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HETCH HETCHY RESERVOIR

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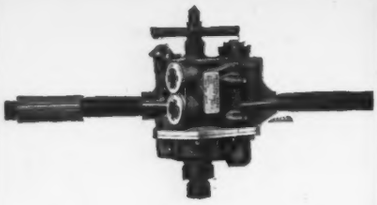
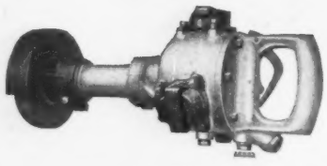


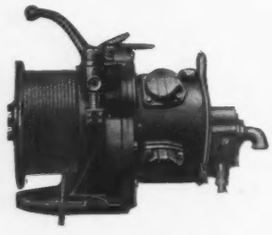
DRILLS



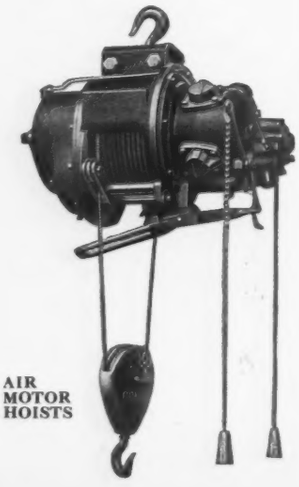
GRINDERS

CHIPPERS

RIVETERS



"UTILITY" HOISTS



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INGERSOLL-RAND PNEUMATIC TOOLS

As It Seems To Us

THE ANTIQUITY OF GLASS

PRE-CHRISTIAN Rome and Greece counted glass next in value to gold. Those peoples obtained their glass from Egypt, the skill of whose artisans founded a lucrative export trade that endured for many years. At Alexandria were furnaces from which came exquisite creations that are today prized highly by collectors. Just when this trade started is obscure, but Aristophanes mentioned it in 450 B.C., and a celebrated Greek painting of the Fourth Century, B.C., reveals Methē, or "Intoxication" drinking from a glass bowl through which her face can be seen.

When Caesar conquered the Egyptians, he directed that they pay a portion of their tribute in glass. Curiously enough this proved a boon. More Romans saw and desired some of the ware, and the resultant demand brought unprecedented prosperity to the glassmakers. Egypt retained its monopoly until 14 A.D., when, during the reign of Tiberius, the industry was established in Rome.

"The reasons why the center of glass-making remained in Egypt for some time after the conquest are varied," writes L. M. Angus-Butterworth in *The Glass Industry*. "One cause was because the sand of Alexandria was considered indispensable for the finest qualities. Again, inherited skill and the fact that the furnaces were already erected no doubt played their parts."

All early glassware took the form of vessels—glasses, vases, and bowls. Window glass was used but little until the Third Century, B.C.

OUR SWEET TOOTH

IF YOU are an average American, you consumed about 9 pounds of candy in 1932, according to figures compiled by the Department of Commerce. Collectively, the nation ate, or at least bought, the astonishing amount of 1,168,848,982 pounds of this form of confection. This was 1.3 per cent greater than the 1931 consumption. Because of falling prices, however, the return to the manufacturers was 19.6 per cent less than in the preceding year.

The primary reason for the increased consumption, according to Federal statisticians, is the enlargement of the popular 5-cent bar. Other contributing causes are: improved merchandising methods, including more attractive packaging and rendering the bar easier to eat either by slicing it or by wrapping two small pieces in a package which formerly contained one large one.

Although those who gathered and interpreted the figures are likely correct, we hold the private and unofficial opinion that the depression, itself, spurred the sale of candy bars. For corroborative testimony we should like to call upon the thousands of city office workers who have been compelled to cut down on their expenditures for the noonday meal.

THE BOUNTY OF ALASKA

UNCLE Sam may not be the shrewdest bargainer in the world, but Lady Luck seems always to walk at his side when he goes to market to buy land. In their purchase of Manhattan Island, the Dutch appear to have set a standard of sagacity which has been well maintained. If one will list through the acquisitions of territory, one will perceive that almost always the dollars, or their equivalents, which have gone in exchange for real property have returned with bountiful interest. We are reminded of these things by the report of the United States Geological Survey that in 1932 Alaska produced in gold alone $10,209,000, or $3,000,000 more than was paid to Russia for the territory in 1868. Alaska is rich in other minerals, including coal; its timber resources are enormous; and its annual yield of fish and furs nets a tidy sum.

Formerly called Russian America, this vast expanse of continental and insular land was popularly considered as something of a white elephant until the fabulously rich gold strikes in the Klondike stirred the public interest and imagination. Since then it has become a prolific producer of many forms of wealth, and has drawn an increasingly greater throng of settlers. Its population now consumes a sizable bill of goods each year, most of it bought in the United States. In addition to all these tangible sources of wealth, Alaska will some day prove valuable as a base for aerial transportation to Asia. Already one American owned company is operating commercial planes there on a regular schedule, and is using this foothold to survey routes for contemplated extensions of service into Siberia and thence to the Orient.

To return to Alaska's 1932 mineral production: Despite the low ebb of metal mining generally, the total value of minerals dug was only 5 per cent below the 1931 aggregate. This record is considered exceptionally good, and is taken as convincing evidence that the Alaskan mining industry is on a sound, fundamental basis. Alaska is still a new mining field—its vastness and the severity of its winters having limited the scope of development. Placer mining is still important, so much so in fact that it accounted for 54 per cent of the gold taken in 1932. It augurs well for the future of Uncle Sam that he has in reserve Alaska's great storehouse of natural resources.

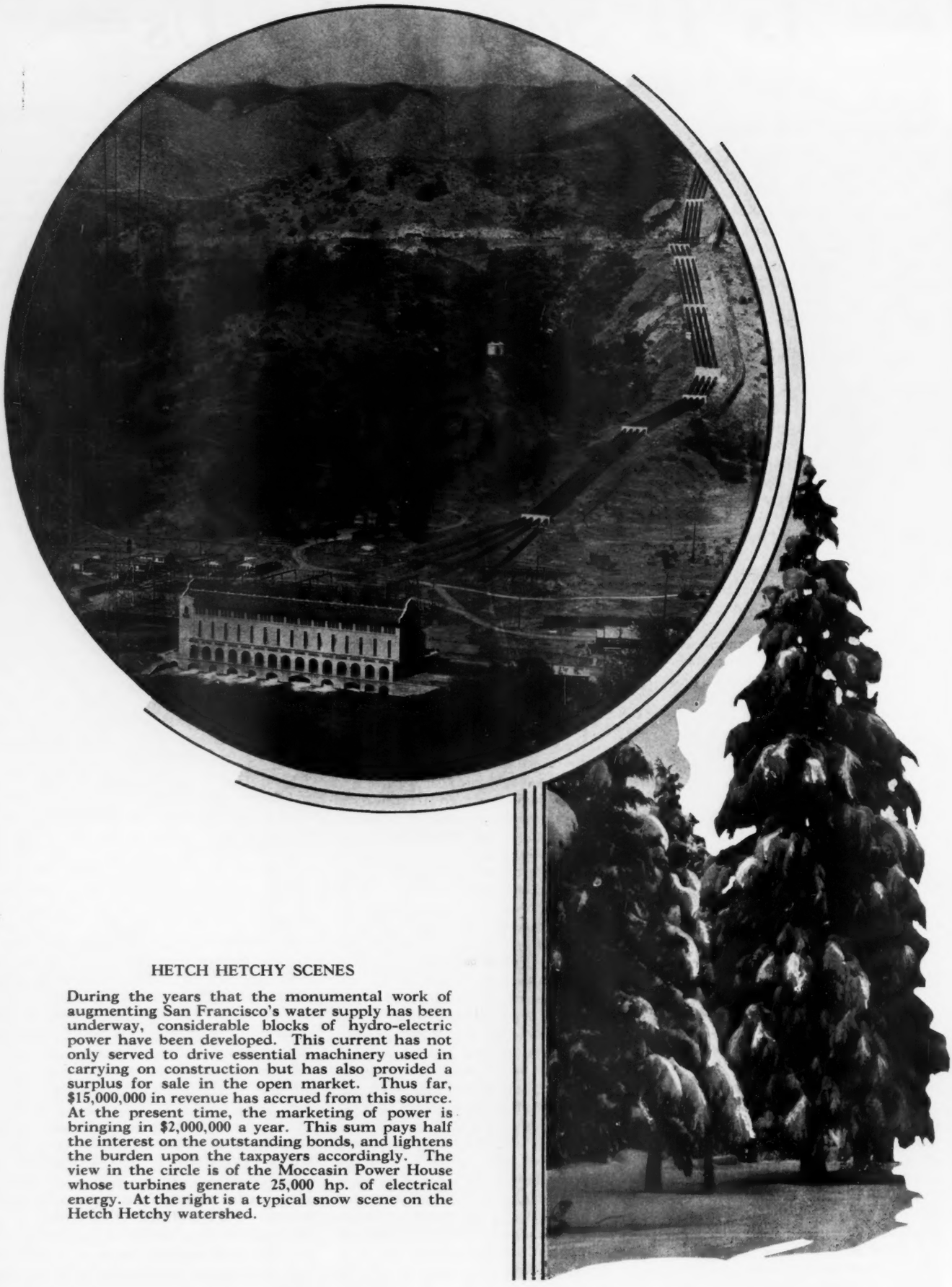
MORE ROADS QUICKLY

THE sum of $400,000,000—approximately 12 per cent of the public-works fund of $3,300,000,000 created by the National Industrial Recovery Act—was made available for road construction in the several states on July 1. It is stipulated that this money shall be spent within the two years that the act is to be operative, but the Bureau of Public Roads promises to do even better than that and to spend it all inside of one year.

The chief purpose of this roadbuilding program is to provide employment—the needs of various sections for roads being subordinated thereto. Those communities that have the greatest number of idle men will get the greatest mileage of highways. The provisions of the legislation are the broadest ever to be written into such an enactment. Under those liberal terms, half the money will be applied to projects on the Federal-aid system outside the corporate limits of towns and cities; at least 25 per cent will go towards the extension of the Federal-aid system into and through municipalities; and a minimum of 25 per cent will be spent for secondary or feeder roads. While the last provision has not been finally interpreted, it is believed that it will permit expenditures within towns and cities on such streets as can be rightfully considered feeders to through Federal-aid highways. As administered in the past, Federal-aid appropriations have rarely been made applicable to roadbuilding within corporate boundaries.

The new bill also provides that some of the money can be spent in eliminating or reducing hazards. This means that it can be used for correcting dangerous curves, widening curves and bridges, building sidewalks for the protection of pedestrians, or even for the lighting of highways. It also will make it possible to provide grade separations at railroad crossings without waiting until the railroads concerned have the money to defray what has previously been considered their share of such undertakings. To lengthen the payrolls to the fullest practicable extent, the roads are to be built by hand labor wherever such labor will not excessively increase costs.

Under the allocation of funds, every state will have at least $1,000,000 to spend. Texas, with more than $24,000,000, leads the list, and is followed by New York with more than $22,000,000, and then by Pennsylvania with nearly $19,000,000. The $400,000,000 is available without strings—that is, the states do not have to match Federal appropriations. Because of this and also because there is in the various states a backlog of projected highways for which plans are ready, it is believed that the program will get underway without delay.

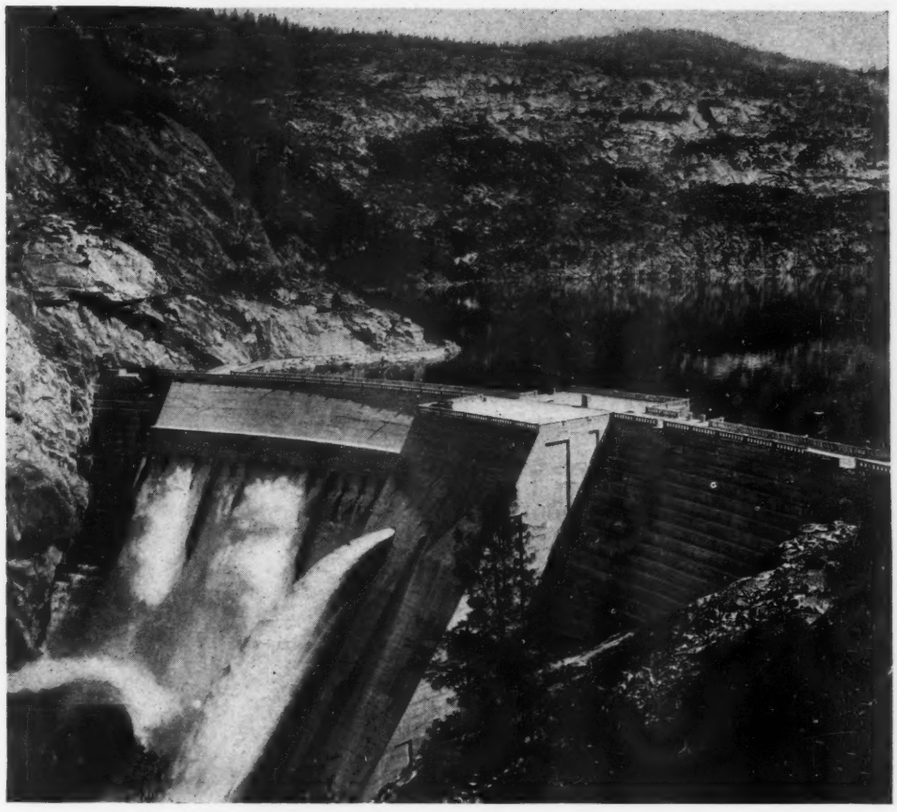


HETCH HETCHY SCENES

During the years that the monumental work of augmenting San Francisco's water supply has been underway, considerable blocks of hydro-electric power have been developed. This current has not only served to drive essential machinery used in carrying on construction but has also provided a surplus for sale in the open market. Thus far, $15,000,000 in revenue has accrued from this source. At the present time, the marketing of power is bringing in $2,000,000 a year. This sum pays half the interest on the outstanding bonds, and lightens the burden upon the taxpayers accordingly. The view in the circle is of the Moccasin Power House whose turbines generate 25,000 hp. of electrical energy. At the right is a typical snow scene on the Hetch Hetchy watershed.

San Francisco's Hetch Hetchy Project «»»

LAWRENCE A. LUTHER



O'SHAUGHNESSY DAM

This structure is named for M. M. O'Shaughnessy who, since 1912, has directed the notable engineering enterprise which is enabling San Francisco to reach back 170 miles into the mountains for its water supply. The dam, rooted in bedrock, rises 226.5 feet. Back of it the waters of the Tuolumne River are impounded in Hetch Hetchy Reservoir, 7.5 miles long and capable of containing 67,000,000,000 gallons. Provisions have been made for ultimately raising the dam 85.5 feet, thereby increasing the reservoir capacity by 70 per cent.

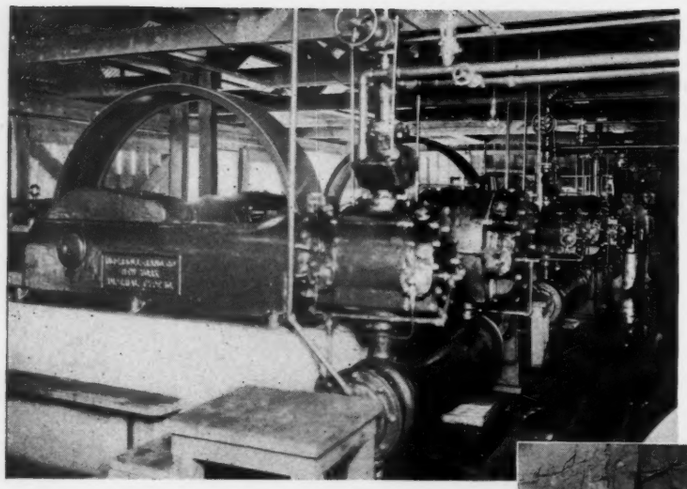
TO MAKE incomparably pure mountain water flow entirely by gravity some 170 miles from the High Sierra to reservoirs above the Golden Gate is truly an ambitious and unique idea, and the practical working out of the plan has proved as interesting as the conception was daring. Not content with bringing this water practically at sea level across a great inland valley, through 28½ miles of tunnel in the Coast Range, and beneath San Francisco Bay to discharge in the coastal highlands, the dreamers of this great utilitarian dream sought to employ its rapid fall through mountain and foothill sections in generating electric current. One of the several projected hydro-electric plants has, in fact, been in operation since 1925 and, besides supplying power for construction work, has earned nearly $15,000,000 through surplus power sold.

San Francisco was not particularly favored by nature in the matter of water supply, for as a city of 8,000 souls its water mains were some half dozen mule-drawn carts. Employing casks and kegs, procured from local saloons, instead of goatskin water bags, it was somewhat more modern but less picturesque than Old Spain. The city's experience in procuring water was strikingly similar to that of another notoriously straggling, hilly village some 2,000 years ago. Frontinus, hydraulic engineer and one-time Roman governor of England, in his history of the aqueducts of Rome, said: "For four hundred and forty-one years after the building of the city the people were content with the water which they could draw from the Tiber or from wells or springs."

Sources near San Francisco Bay were developed first by a local company which gradually went farther and farther afield until the possibilities of all local watersheds had been exploited. Some of the nine aqueducts which radiated from the Eternal City extended more than 60 miles to reach suitable supplies, and they have never ceased to be impressive as creations of the fledgling science of engineering. But their conduits of mortar and stone could sustain only a few pounds of hydrostatic pressure; and were we to envisage Roman aqueducts as serving in lieu of the pipe lines which will convey the waters of San Francisco's Hetch Hetchy project across the San Joaquin Valley, their supporting arches would have to be quite 800 feet high. The static head at the crossing of the San Joaquin River is 740 feet, or some 320 pounds—one and one-half times that which will be delivered to the turbines in the Hoover Dam power houses.

A true and complete telling of the story of these modern aqueducts would require a sizable volume and would be as much a human drama as a record of engineering and economic detail. When the present chief of the engineering staff, M. M. O'Shaughnessy, assumed responsibility for the carrying through of this vast and ramified undertaking in 1912, he doubtless foresaw in it no sinecure nor ordinary industrial adventure. Scarcely a year has passed without presenting from some source—political, economic, or physical—what seemed for a time to be an impasse. When the last barrier of rock shall have been penetrated, and San Francisco housewives discuss across backyard fences the softness of the mountain water, this monument, which almost spans the state, will begin to live and testify to the fidelity and vision of its builders. The aqueduct, now nearly completed, would have been placed in service in 1932, as scheduled, had not delayed financing and well-nigh insuperable combinations of difficult ground and highly inflammable gas seriously retarded progress in the Coast Range tunnels, a section of which will amount to 25 miles of continuous bore, the longest tunneling operation ever undertaken.

As a culmination of exhaustive analyses of fourteen possible sources of supply, begun in 1882, initial efforts to acquire the desired drainage areas were made in 1901. The first high hurdle to be crossed was the acquisition of a federal grant to the desired lands, for these lay largely within the boundaries of Yosemite National Park which, even at the beginning of the century, had acquired international renown as a scenic wonderland. John R. Freeman, a noted hydraulic engineer, was engaged by the city in 1910 to design a

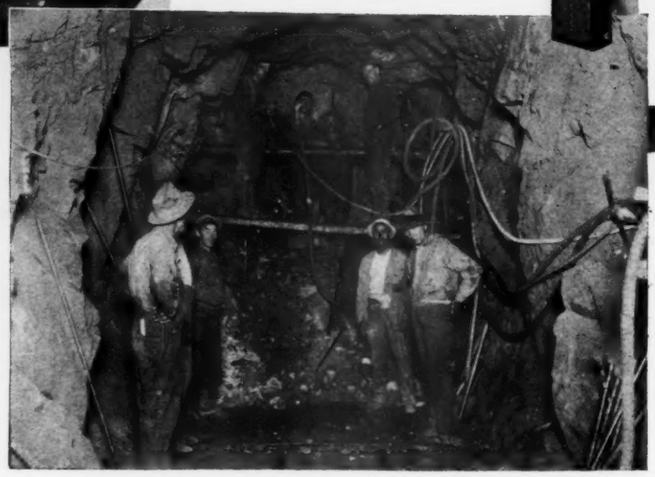


COMPRESSORS AND DRILLS

Compressed air and rock drills have had leading parts in this vast work. Steam-driven compressors served at first—electrically driven units being installed as power became available. Shown above are Type XB-2 machines belt driven from motors. At the right is a view at the breast of one of the few tunnels where the rock was stable. Methane gas is a constant hazard, however, and has required the development of special means to combat it. The picture is fifteen years old—no photography having been permitted in gaseous workings in recent years.

FIGHTING INVISIBLE DEATH

Because of the gaseous workings, 1,500 men have been trained in mine-rescue practice. At the right are shown two of them wearing their equipment. On the opposite page is pictured one of the fire bosses who continually patrol the tunnel sections to detect gas as soon as it appears.



complete system and to prepare material with which to substantiate the city's claim before Congress. President Taft later appointed a board of army engineers to investigate thoroughly all alternative sources of supply available for San Francisco, with the result that the Freeman Plan was approved. The Raker Act, signed by President Wilson in December, 1913, represented the hard-won issue of a lively and extended battle waged in the halls of Congress. Contending claims of power and irrigation interests, and intervention of national-park enthusiasts, served seriously to obstruct essential legislation and resulted in the writing into the act of complicating and restrictive clauses. The result has, nevertheless, proved highly satisfactory; and, inasmuch as the watersheds which must be protected lie in the northern and undeveloped section of the vast Yosemite playground, the appeal of the park has been in no wise impaired.

The aqueduct system is designed for an ultimate capacity of 400,000,000 gallons of water daily, with inherent hydro-electric-development possibilities amounting to 250-000 hp. The almost Alpine contours of the 650-square-mile watershed descend from the snowy crest of Mt. Lyell, at elevation 13,090, to 3,800 feet at the principal mountain reservoir. The builders conspired virtually to make plunging mountain streams bore their own tunnels through some 80-odd miles of earth and rock, and their methods have proved notably successful. This harnessing of the waters to the task of digging and building was the first major item on the program; but before even a small and more or less temporary power plant could be created, a means of transportation for material and machinery had to be provided through extremely rugged country. The magnitude of the principal undertaking begins to be seen in its true perspective when we learn that 68 miles of standard-gauge railroad were required for the transportation of machinery and construction materials.

A decade has elapsed since the publication serially in this magazine of four articles prepared by Nelson A. Eckart and Leslie W. Stocker of the Hetch Hetchy engineering staff. Those articles covered in detail the preliminary phases of the undertaking and the construction of the two dams which have created the necessary impounding reservoirs. It was told how complete logging and sawmill equipment was employed to supply lumber for the vast amount of crossties, mine timbering, flumes, and concrete forms required. An administrative headquarters for work on the mountain and foothill divisions, established at the Village of Groveland, included warehouses, shops equipped to repair every type of equipment used, a hospital, and other essential facilities.

Water power was drafted hastily into service by diverting the flow of the Cherry River through a mile of tunnels, a mile of concrete-lined canal, and 1½ miles of flume to a power house located near the head of the aqueduct at Early Intake. Three 1,500-hp. generating units were driven at a head of 345 feet, and the current, stepped up to 23,000 volts, was distributed to the various widely separated centers of operation and applied to every sort of power requirement. In the driving of these preliminary power tunnels, Type 14 gasoline-engine-driven portable compressors were employed to operate No. 18 drifters and BCRW-430 "Jackhamers."

Seasonal fluctuations of flow in Cherry River made a storage reservoir essential to continuous operation of the power plant. A buttressed arch dam, 1,260 feet long and with a maximum height of 70 feet, was made to increase the capacity of Lake Eleanor—a natural glacial lake—to the amount of 9,000,000,000 gallons; and one of the details of the projected development is increasing the height of this dam to 235 feet.

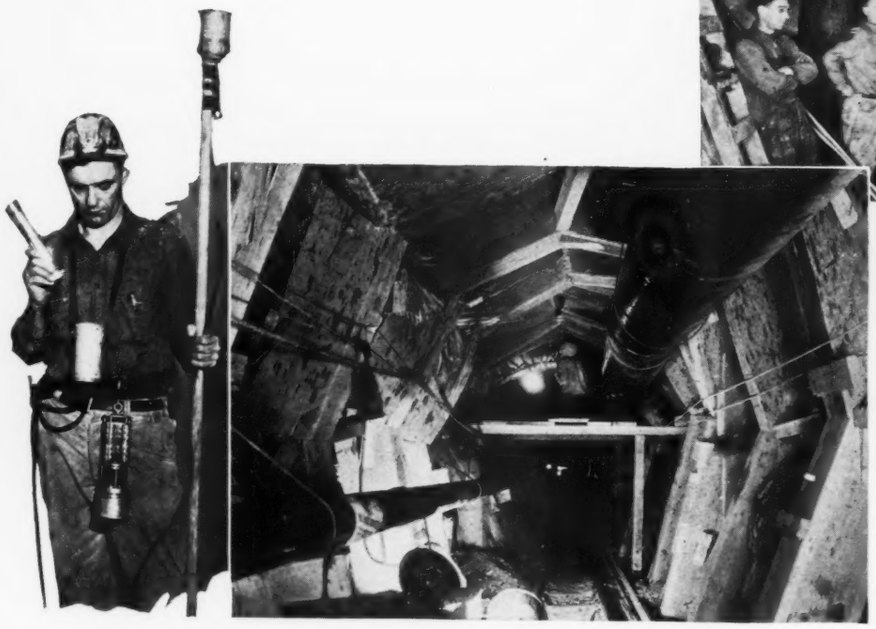
The largest single structure in the aqueduct system is O'Shaughnessy Dam on the Tuolumne River. This dam, which is of the arched gravity type, is 605 feet long, stands 226.5 feet above the stream bed, and contains a total of 398,516 cubic yards of concrete. At the instance of Mr. O'Shaughnessy, the original foundation plans were revised to incorporate anchorage of the entire foundation directly in bedrock, which involved excavating as deep as 118 feet below the stream bed. Foundations have a maximum thickness of 298 feet, making provision for an ultimate increase of 85.5 feet in height, which will add some 70 per cent to the present capacity of the 7.5-mile-long, 67,000,000,000-gallon reservoir.

During the construction of the dam, the river was diverted through 900 feet of 23x25-

TUNNELING UNDER DIFFICULTIES

Hetch Hetchy's bores are being driven in the face of almost insurmountable odds. The picture below shows how even closely spaced heavy timbers buckle under the tremendous pressure exerted in the Coast Range, where every foot of the 28.5 miles of tunnels has to be supported as work progresses. The placing of permanent reinforcement involves the liberal use of concrete, grout, and gunite.

Quicksand that on one occasion filled 1,800 feet of tunnel and required three months to remove has been one of the bugaboos of the Coast Range tunnelers. At the right are seen breast boards holding up the tunnel face while workmen clear away gouge material.



foot tunnel driven through the granite wall of the canyon. Electric current not having been made available, a 750-cubic-foot X-2 steam-driven compressor was employed to supply air to No. 18 drifters in driving this tunnel; and the equipment was later utilized in excavating for a diversion structure. The dam was built at a cost of approximately $8,000,000 on a contract awarded in 1919 to the Utah Construction Company.

The aqueduct proper may be said to begin at Early Intake, the water following stream beds to this point. But some 100,000 potential horsepower of hydro-electric energy, now wasting in foaming riffles and cascades, is eventually to be mobilized by the construction of two generating plants with their requisite tunnels. To these streams, which through countless centuries brought down and stored in bars of sand and gravel the yellow dust whose discovery electrified the world in '49, will be assigned the performance of prosaic tasks in the bay cities. At Early Intake a somewhat elaborate concrete diversion dam, 81 feet high inclusive of foundation, regulates the entrance of the water into the nineteen miles of tunnels in what is known as the Mountain Division. These tunnels range from 10 to 14 feet in diameter and, with the exception of eight miles driven through granite, are lined with concrete. Driving was carried on from twelve faces: four were advanced from portals, four from adits, and four from the bottoms of two shafts, the deeper of which was 786 feet. All this excavating was done with power from the construction power plant previously mentioned. Among the electrically driven compressors supplying air to the several faces were a number of 704-cubic-foot XB-2 machines; and No. 248 drifters and BCRW-430 "Jackhamers" were employed, respectively, in driving and sinking.

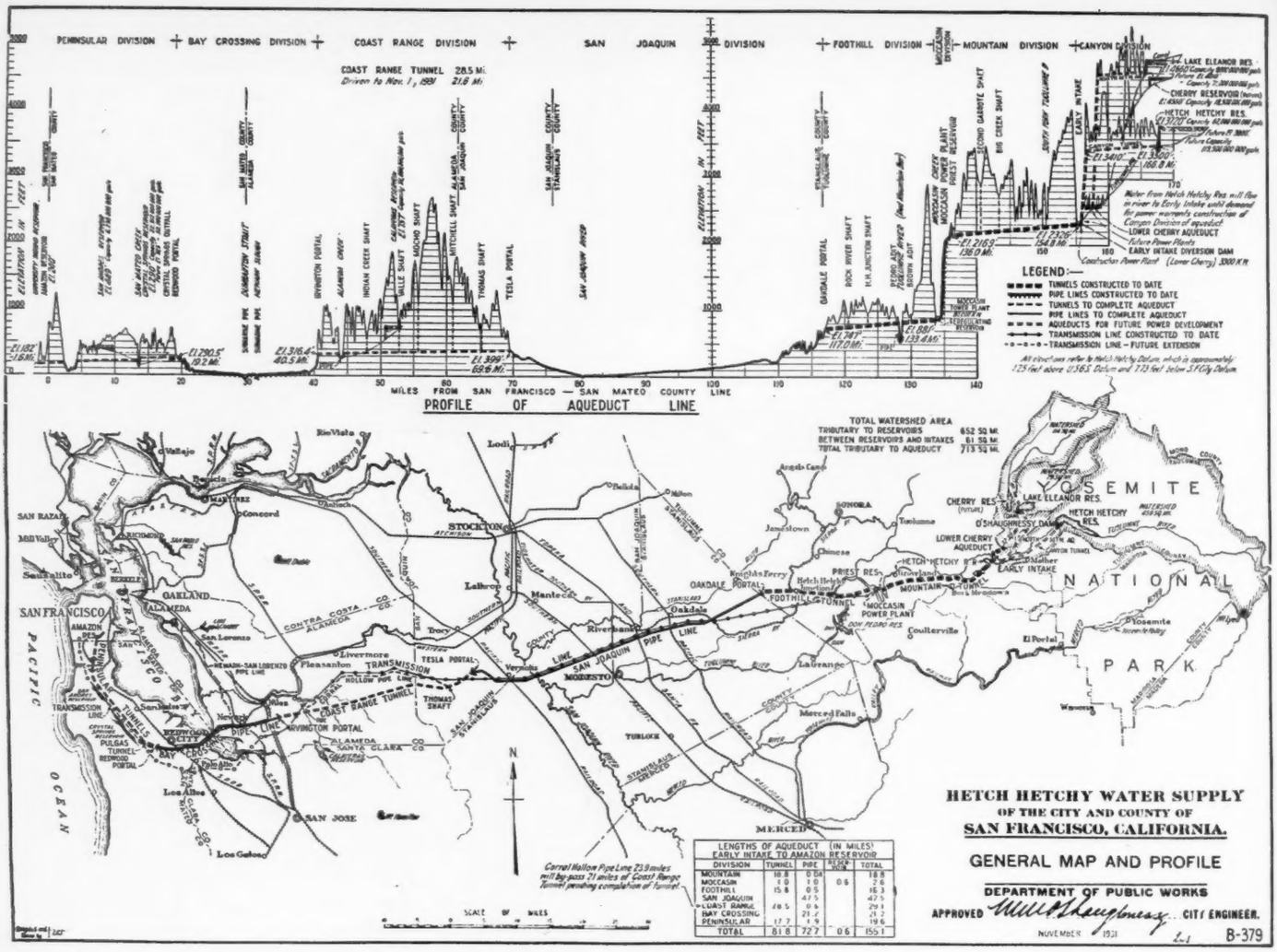
Most frequent and baffling encounters with water-bearing strata occurred in sinking Second Garrote Shaft—the total flow which had to be pumped out mounting to as high as 2,000 gpm. In fact, water poured in so rapidly that, had pumping been stopped, the men would have been forced to step lively in climbing the ladders. Exploratory drill holes were kept about 14 feet below the shaft bottom; and, when water veins were tapped, thin grout was fed at pressures as great as 400 pounds into holes which angled out and downward at the junction of bottom and walls. The dewatering equipment at this location included three Cameron 5-inch, 3-stage ST pumps of 750 gpm. capacity each, a No. 7 and a No. 9-B air-driven sinking pump, and a standby air-lift installation with an X-2 steam-driven compressor.

The nineteen miles of Mountain Division tunnel and the 225 feet of 9.5-foot-diameter steel pipe crossing the south fork of the Tuolumne River bring the water to Moccasin Power House. Widely fluctuating power demands necessitated a forebay reservoir which, through the construction of a 147.5-foot-high, 1,160-foot-long earth-fill dam with a sectionalized concrete core wall, has been created with a capacity sufficient to store two days' flow of the aqueduct. Water is drawn from this reservoir through six electrically operated sluice gates in a control tower and carried by a mile-long rock tunnel to a 40-foot-diameter surge shaft serving as a manifold for the penstock pipes. Three of these 104-inch-diameter pipes, equipped with suitable butterfly valves and expansion joints and carried on heavy reinforced-concrete saddles, extend for 5,349 feet, where one is dead ended pending the installation of two additional turbines. The two pipes in service are first reduced in diameter to 98 inches; branched to two 3,469-foot pipes ranging in diameter from 66 to 54 inches; and, immediately before entering the power house, branched again to two 36-inch-diameter pipes which supply nozzles automatically controlled to deliver water sufficient to meet varying current requirements.

A reinforced-concrete power house built in the Spanish style, 225 feet long by 98 feet wide, houses four 11,000-volt generating units whose double overhung impulse-type water wheels total 25,000 hp. The 118-ton rotating elements of each unit operate under an effective head of 1,250 feet at 257 rpm. Transformers installed adjacent to the power house step up the current to 115,000 volts; and a double-circuit transmission line, whose supporting towers for 98½ miles occupy the 110-foot right of way acquired for the construction of pipe lines across San Joaquin Valley, carries it to a Pacific Gas & Electric station located at Newark on San Francisco Bay.

Sharp variation in the consumption of the water wheels requires that the flow be reregulated before again entering the aqueduct, and a 160,000,000-gallon reservoir has been provided 1,500 feet below the power house through the construction of an earth-fill dam. Entrance to the next element of the aqueduct, 15.8 miles of tunnel through the Sierra foothills, is governed by electrically operated sluice gates housed in a concrete tower.

The only interruption in the foothill tunnel is 2,514 feet of 9.5-foot-diameter steel pipe which crosses the canyon of the Tuolumne River in the form of a siphon. On the easterly


PENINSULAR DIVISION
BAY CROSSING DIVISION
COAST RANGE DIVISION
SAN JOAQUIN DIVISION
FOOTHILL DIVISION
MOCCASIN DIVISION
MOUNTAIN DIVISION
CANYON DIVISION
PROFILE OF AQUEDUCT LINE
MILES FROM SAN FRANCISCO — SAN MATEO COUNTY LINE
LEGEND:—
TUNNELS CONSTRUCTED TO DATE
PIPE LINES CONSTRUCTED TO DATE
TUNNELS TO COMPLETE AQUEDUCT
PIPE LINES TO COMPLETE AQUEDUCT
AQUEDUCTS FOR FUTURE POWER DEVELOPMENT
TRANSMISSION LINE CONSTRUCTED TO DATE
TRANSMISSION LINE — FUTURE EXTENSION
TOTAL WATERSHED AREA
TRIBUTARY TO RESERVOIRS 652 SQ MI.
BETWEEN RESERVOIRS AND INTAKES 61 SQ MI.
TOTAL TRIBUTARY TO AQUEDUCT 713 SQ MI.
YOSEMITE NATIONAL PARK
HETCH HETCHY WATER SUPPLY
OF THE CITY AND COUNTY OF
SAN FRANCISCO, CALIFORNIA.
GENERAL MAP AND PROFILE
DEPARTMENT OF PUBLIC WORKS
APPROVED M. M. O'Shaughnessy CITY ENGINEER.
NOVEMBER 1931
B-379
LENGTHS OF AQUEDUCT (IN MILES) EARLY INTAKE TO AMAZON RESERVOIR
DIVISION | TUNNEL | PIPE | RESERVOIR SIDE | TOTAL
MOUNTAIN 18.8 0.04 18.8
MOCCASIN 1.0 1.0 0.6 2.6
FOOTHILL 15.8 0.5 16.3
SAN JOAQUIN 42.5
COAST RANGE 28.5 0.4 29.1
BAY CROSSING 21.2
PENINSULAR 17.7 1.9 19.6
TOTAL 81.8 72.7 0.6 155.1

PLAN AND PROFILE OF THE HETCH HETCHY SYSTEM

canyon wall a concrete sand trap has been provided, and the west wall carries an overflow structure. Foothill tunneling was carried on from ten headings, two shafts being sunk to tunnel line. Water-bearing veins proved a serious handicap in this work—an example being a flow of 700 gpm. at 380 pounds pressure tapped in the Moccasin Portal heading. Twenty-one separate shutdowns were caused by water flows encountered in a single year in advancing this one heading, with a resultant loss of 65 working days. This does not include all the delays incident to drilling and to injecting grout under high pressures to seal off the water, in which latter work 2,344 sacks of cement were consumed. A monthly advance of 803 feet was made in one of the headings, a record for tunnel-driving in hard rock.

Ultimate plans call for three separate lines of pipe in the 47.5-mile San Joaquin Valley span extending from Oakdale Portal, at elevation 747 in the foothills, to Tesla Portal, elevation 399, at the base of the Coast Range. One 5-foot-diameter line with a daily capacity of 60,000,000 gallons, adequate for immediate requirements, is now ready for service. This pipe, as well as the power-house penstocks and the bay-crossing pipe, was fabricated by Western Pipe & Steel Company. Contract for laying the San Joaquin line was awarded to Youdall Construction Company. It is made up of welded steel pipe with riveted field joints and the section that runs below two waterways is both lined and coated with concrete. Concrete saddles supported by pile bents support the line on unstable ground, and the protective coatings employed range, as corrosive properties of ground conditions dictate, from those obtainable by dipping in asphalt and wrapping with asphalted felt to casings of reinforced concrete.

The aqueduct through the Coast Range consists of two sections of tunnel 25 miles and 3.5 miles long, respectively, and of an 0.6-mile pipe line where it crosses a valley. The 25-mile tunnel, a unique undertaking, was driven from twelve headings. Strategic points were selected for sinking five shafts close to the tunnel line, the deepest being 823 feet. Crosscuts were driven in opposite directions from these shafts to the line of the present tunnel and to the line of a second paralleling tunnel which is to be driven when conditions may require. The city transmission line was tapped at a point nine miles from Livermore; a substation was erected; and 22,000-volt current was distributed to all tunnel camps.

Hard rock is no longer the Nemesis of tunnel drivers, for granite has become almost plastic in the hands of modern miners. Man's conquest of rock, of Neanderthal origin, has been slow, for little advance in the art was made in the days of the Caesars. Sooty, gasping slaves from Gaul and Saxony, under the whips of bestial Roman drivers, built great fires against a tunnel face and split off a few inches each day by alternately heating and quenching with water. Iron, the sinew of modern industry, was many centuries in transition from metal fit for spears and cart tires to steel tough enough to cut rock and sustain the beating of sledges. Diamond-like abrasives under saws and tube drills served experts of an ancient epoch; and tunnel-driving appears to have paralleled pretty closely the fate of the arts, with a lapse through the Dark Ages and a belated renaissance almost within the memory of men now living. The era of tunnel-driving in the Alps, that was initiated back in 1857, saw the gradually developing mechanical drill raise the average advance of 9 inches per day, made by

the hand drill, to 20 feet.

Nearly two decades have passed since the breaking of ground on this Hetch Hetchy project, a period registering unprecedented advance in the technique of and in the facilities for rock excavation. The No. 18 water "Leyner" drills purchased on the initial order represented a long stride forward in man's mastery of rock, making the piston drills of the Alpine tunnels appear archaic. Yet their apparent perfection was little more than an augury of what modern drifters would accomplish, for performance, measured in inches per minute of hard rock penetrated, has been tripled.

With all modern facilities at their command, and qualified by a long and rigorous apprenticeship served in burrowing through 35 miles of every variety of rock found in the Sierra Nevada, it would appear to a layman that the miniature mountains of the Coast Range should represent no unduly imposing barrier to these veterans of the Hetch Hetchy. But Mother Nature has other and more sinister combinations than hard ground and water veins; and this first underground journey through the Coast Range has disclosed a unique assortment of hazards insurmountable by any standardized method.

As measured by the scale of geologic time, the Coast Range is something of an adolescent. Geologists lead us to believe that those hills, green in the spring and changing to browns and grays after a rainless summer, have looked about as they do now for a million years or more and that their placid exterior conceals an inner unrest and instability. The present epoch sees work going forward beneath the earth's crust perhaps a little more slowly than ever before; and, inasmuch as man's span of life is so minute a segment of cosmic time through which to gather and correlate data, intense interest attaches to any section showing evidences of unusual activity. Geologists follow the boring of a tunnel like the one through the Coast Range with keen interest. Here and there they discover a fossil or a stratum of rock whose record of ages past fits neatly into the intriguing jigsaw puzzle which constitutes geological research.

Typical of the varied earth and rock formations encountered was a pocket of quicksand penetrated in advancing the heading from Indian Shaft toward Alameda Portal. Dr. Bailey Willis, a consulting geologist employed by the city, gave this material the highly descriptive name of "incoherent sand," explaining in scientific terms its origin and history and ascribing reasons for the vagrant characteristics which caused it to pour rapidly in through the heading and to fill completely some 1,800 feet of the bore. It is estimated that this sand entered at a pressure of about 200 pounds. The tunnel was cleared by excavating the upper section in stretches of several hundred feet and then by constructing bulkheads to the tunnel floor to give protection while removing the sand in the lower section. A second heavy flow was encountered soon after starting this work, and three months were expended in clearing the tunnel. The attendant 2,000-gpm. flow of water had attained a depth of 3 feet in the crosscut before a crew could be brought out from the opposite heading. This sand flow was typical of several encountered at widely separated locations.

When we know that not one foot of the 28.5 miles of Coast Range tunnels penetrates rock sufficiently hard and impervious to serve without lining, we gain a vague conception of the prevailing instability of the ground; and when field men assure us that at certain locations 18x24-inch timbering placed on 2.5-foot centers will stand but a few hours without requiring replacement and that 10-inch breast boards are frequently compressed to a thickness of 3 inches, then our conception of the terrestrial pressures which strive incessantly to close these tunnels is tinged with awe. At many locations the ground swells—moves upward against the floor as well as sideways against the arch and walls—at a rate of 2 feet in 24 hours. Guniting with grout, in which calcium chloride is employed as an accelerator, has throughout a large portion of the Coast Range tunnels proved the only practical solution.

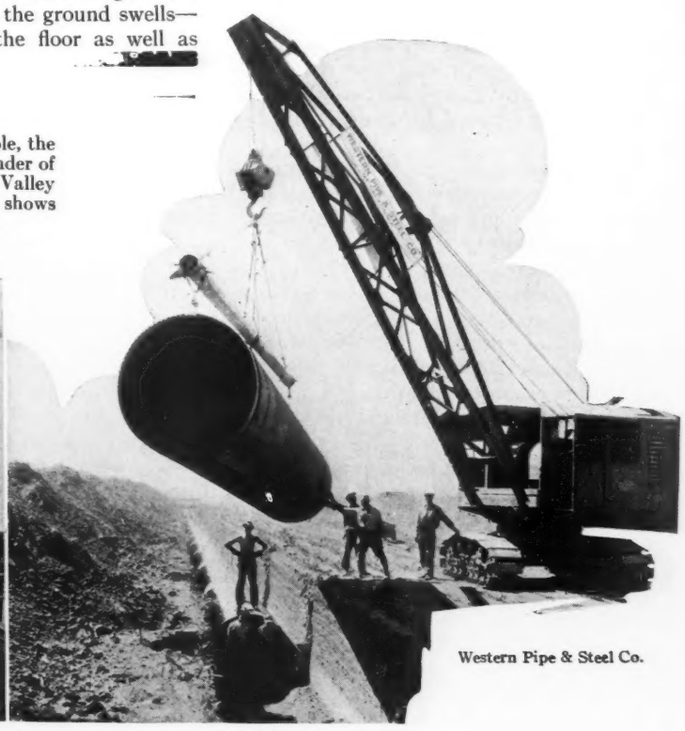
In coping with continually changing formations, variations are, of course, made in procedure; but the process, roughly speaking, consists of advancing the heading a distance of 6 feet, bracing up the face when necessary with breast boards, drilling a series of holes in the face for the insertion of crown bars to support the sides and roof, and then rapidly building up a complete ring of gunited material. The tunnel is subsequently finished to standard dimensions by using portable forms and injecting concrete from a pressure gun through piping. Four model HU "Utility" air hoists are employed by the concreting crews in drawing cars of mixed concrete up a specially constructed incline for transfer to pneumatic guns. A No. 2015 electric double-drum "Tugger" hoist has been recently employed with marked economy for slushing in removing rails and ties and in cleaning waste material from the finished tunnel.

Stratification and the nature of the material excavated have changed with unprecedented frequency and irregularity, so that calculations of progress based on existing geological charts have proved too wide of the mark to be helpful. It is a little strange to see drifters drilling rock and clay diggers spading out soft material simultaneously in a heading. RB-12 "Jackhamers" using auger steel have been employed advantageously in certain kinds of ground.

Generous provision for ventilation and conventional precautions against encounters with poisonous or explosive gases were made a part of the program on starting work in the

CROSSING THE BAY

Nearing San Francisco the line crosses the bay. Where the water is navigable, the pipe is laid in a trench as much as 70 feet below mean low tide. The remainder of the bay crossing is made by trestle, as shown below. Across San Joaquin Valley the watercourse is a steel pipe line 5 feet in diameter. The view at the right shows how modern machinery facilitated the handling of the huge tube sections.



Western Pipe & Steel Co.

VERSATILE SERVANT

Compressed air does man's bidding in many ways on this big job. At the left is a blacksmith shop equipped with an air-operated furnace and a sharpener for reconditioning drill steels. The man in the center is using a Size 4F pneumatic grinder equipped with a wire brush to clean a form that has seen service in concreting. At the right a compressed-air drill is mounted on a special device for driving a screw that forces calking lead into the joints of the pipe constituting the aqueduct in the nontunnel sections.

Coast Range; but there was nothing to indicate the existence of the gas deposits found in certain sections. Methane, a combination of hydrogen and carbon, entirely colorless and odorless but highly inflammable when mixed with air in a proportion of from 5 to 15 per cent, has complicated the task and increased expense quite as much as heavy ground. An explosion occurred in July, 1930, in a heading advanced westward from Mitchell Shaft in which twelve men lost their lives. Work was suspended at all camps, and the State Industrial Accident Commission in collaboration with the U. S. Bureau of Mines made exhaustive studies and formulated rules governing operations underground. Long delay resulted from the necessity of providing "permissible" locomotives; and the Livermore shops lent timely assistance in revamping a number of mucking machines and equipping them with engines which could be driven by compressed air. "Permissible" powder was used for blasting, and a unique exploder devised that guarantees instantaneous contact and provides against the firing of any gas that may be released by shots caused by contact with live wires.

The ventilating system as now arranged consists of combinations of units operated both as blowers and exhausters. No standardized set-up can be applied to all the tunnels—continually changing conditions requiring frequent redesigning of the hook-ups used. Volumes as great as 14,000 cubic feet per minute are exhausted from one heading; and the distance to which suction lines are carried from exhausting blowers—as much as three miles—represents a record in this type of work.

More than 1,500 men have been trained in first aid; and field officials cite this as a most fruitful method of reducing both the number and the serious consequences of personal injuries. Men are thus made "safety conscious." If a worker on this great enterprise can avoid personal injury throughout a week and persuade all his mates assigned to a heading to do likewise, his crew will enjoy a chicken dinner on the following Sunday. This rule is of long standing; several tons of chicken have been awarded; and superintendents testify to the efficacy of the scheme in reducing accidents.

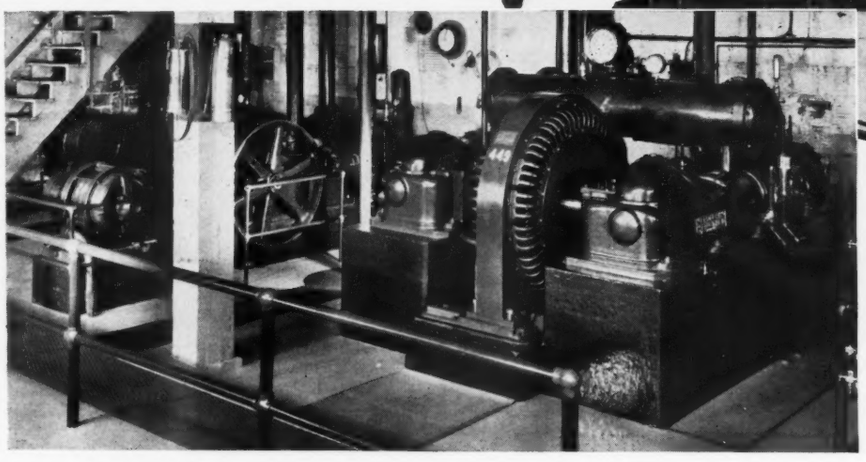
Training in mine-rescue work never before has been carried on so intensively as on this job. Expert crews have been trained and equipped for service at all camps and have made several creditable records in statewide efficiency competitions. It has been estimated that the daily discharge of gas in the tunnels has, for short intervals, mounted sufficiently high to have represented a potential daily income of $300 had it been transmitted to the bay cities and sold at current rates. Coördination of effort between state and federal agencies and Hetch Hetchy officials has been essential to the making of any reasonable progress with the work. The practice of bringing men to the surface before shots has been modified to bringing them a reasonable and safe distance back from the heading. A layman can readily grasp the impossibility of driving tunnels at costs less than prohibitive were it necessary to transport crews through three miles of bore and hoist them 800 feet before firing each round.

Excavating far underground remains, in spite of increasingly safer methods, in the category of somewhat hazardous vocations. Miners accept a measure of danger as routine, yet it is fitting that we note, in passing, the fidelity—amounting on occasions to heroism—of the workmen and supervisory officials who have seen many years of service on this project. Rescue work and dangerous assignments have never failed of volunteers; and the completed aqueduct will be the creation of men who have given their best efforts—some few their lives—to the task.

From the western base of the Coast Range the aqueduct continues as a pipe line 5 feet in diameter and 21 miles long, crossing San Francisco Bay, and terminating in Pulgas Tunnel, 1¾ miles long, which discharges into a storage reservoir at an elevation of 290 feet. The bay crossing pipe is of riveted steel, except for a stretch of 0.6 mile across the navigable channel where 2-inch-thick, cast-iron, flexible-joint pipe was laid in a trench at a maximum depth of 70 feet below water level. The westerly end of this pipe attaches to a concrete caisson of unusual design that forms the first pier of a bridge consisting of thirty-six 105-foot steel spans—the caisson and concrete supporting piers resting on piling. This westernmost section of the system has been already pressed into service as a link in the emergency line which supplements San Francisco's regular supply with water from the watershed of Alameda Creek. Subnormal precipitation on the watersheds heretofore depended upon has served forcibly to bring home to San Franciscans the inadequacy of the present sources of supply and to remind them that the completion of the Hetch Hetchy project will be timely.

Some $80,000,000 have already been invested in this enterprise which is to furnish water sufficient for 4,000,000 people. This marks it as comparable in magnitude to the Boulder Canyon Project, that sum being sufficient to cover the construction of the Hoover Dam proper and partly to install hydroelectric equipment. Original Hetch Hetchy estimates were based on labor costs obtaining at the beginning of the present century; but the complicating influences of the World War began to be felt in the increasing scarcity and cost of essential materials, culminating in the labor famine and high wage scale of 1918. The interest burden of the bonded indebtedness which must be borne by the taxpayers has been lessened by one-half through the application of $2,000,000, annual income from electric power, to the payment of interest.

Compressed Air Helps Build Speedy New Airplanes



FAST TRANSPORT AND EMBLEMS OF PROGRESS

The twin-motored, all-metal plane shown above has a top speed of 190 miles an hour and can cruise at a 170-mile clip with ten passengers, a crew of three persons, and a full load of mail, express, and baggage. For United Air Lines, the Boeing Airplane Company is now building 60 of these new ships, some of which are already in service.

Six years ago the 255-cubic-foot compressor shown at the left in the lower picture served the needs of the Boeing factory. The advent of the all-metal plane increased the demand for compressed air so greatly that in 1932 the 750-cubic-foot unit at the right was installed. The air from these two machines is put to many uses in the thirteen shops that make up the factory, which covers more than 330,000 square feet of floor space.

COMPRESSED air long has been a useful agency in the manufacture of aircraft, and now, that the trend is towards all-metal planes, is assuming even greater importance. Illustrative of this development may be cited the fact that the Boeing Airplane Company, in Seattle, Wash., today uses four times as much air as sufficed to serve its needs until comparatively recently.

The Boeing factory is at present engaged in building for United Air Lines 60 multi-motored commercial transport planes of a type that is claimed to be the fastest in existence. These are all-metal, low-wing, twin-engined units, and they will be used on the various scheduled routes of the purchasing company, including its coast-to-coast service. They have been designed to satisfy the requirements of high operating efficiency, strength, passenger comfort, and flying economy.

Compressed air is helping to put these new air transports in the sky. It operates riveting hammers, drills, bolt spinners, spray guns, reamers, spot facers, sanders and kindred tools. Compressed air goes to the furnaces and lead pots; to the firing systems in the duralumin heat-treating room; to the sand-blasting equipment; to the grinders used in tool and die making; to the routers employed in making wood dies; to the anodic treatment tanks for temperature control and for agitating the anodic solution; to the equipment used in testing fuel tanks; and even to the atomizers in the first-aid room. Almost everywhere about the plant it is in evidence.

Long before construction of the new transports was begun compressed air was preparing the plant for production. Air-driven grinders were helpful in making metal tools and dies, and routers in making wood dies. These dies since have guaranteed precision work and interchangeability, and have enabled large savings in time and labor.

With the start of construction, compressed-air equipment went to work full blast. Thousands of rivets are driven in each of the new transports, with the result that air-operated riveting guns are kept busy. Metal channel sections are employed to a large extent in the internal structure of every plane, and large numbers of these are formed in metal-lined wood dies by the aid of air hammers. No paint is put on the exterior of the transport planes, but spray guns apply primer coats and aluminum lacquer to the interior surfaces. All the other tools and equipment before mentioned are continually in demand in the various shops as the planes take form.

To supply these manifold needs, the Boeing Company uses two Ingersoll-Rand compressors which have a combined capacity of approximately 1,000 cubic feet per minute. Six years ago there was installed a belt-driven Class ER-1 single-stage machine producing 255 cubic feet per minute. This answered until 1932, when the requirements for more air led to the addition of a Type XRE machine with a capacity of 750 cubic feet per minute. This latter compressor is a 2-stage unit with cylinders having respective diameters of 17½ and 10½ inches and a stroke of 12 inches. It is driven by a direct-connected synchronous motor, and is equipped with clearance control which automatically regulates the output in accordance with the demand for air at any particular time. Both of these compressors are now in service.

The air is discharged at 100 pounds pressure; and to free it of oil and moisture before it is transmitted for use it is passed through an aftercooler. It is then distributed through pipe lines to various parts of the factory, which consists of thirteen shops containing a total of 331,000 square feet of floor space.

These planes make possible remarkably speedy transportation of people, mail, and commodities. For instance, passengers leav-

ing the Pacific Coast in the evening have breakfast in Chicago and luncheon in New York. Chicago is only two hours away from Cleveland and four and one-half hours from New York; and breakfast in New York and luncheon in Chicago, or *vice versa*, promises to be the new tempo of airplane travel. Kansas City and Omaha lie within three hours of Chicago, for these Boeing transports of United Air Lines have a top speed of 190 miles an hour and can cruise 170 miles an hour when carrying ten passengers, two pilots, a stewardess, and a full complement of baggage, mail, and express. United Air Lines, the largest air-line operator in the United States, and the speedier planes affect the flying schedules to approximately 137 cities.

Efficient performance, as already indicated, is only one of the features which make this new plane an outstanding development in the commercial air-transport field. Coupled with it is the utmost in passenger comfort, provided by the spacious, heated, and ventilated cabin having upholstered chairs with adjustable reclining backs, dome lights, individual reading lamps, wide windows, and lavatory facilities. The cabin is insulated against both noise and temperature conditions.

A maximum degree of strength is built into the plane. Its all-metal wing will withstand a load of 36½ tons, and the retractable landing gear will bear up under a burden of 32¼ tons. Contrasted with these high factors of resistance is the plane's gross weight of slightly more than 6 tons. Each transport is 51 feet 4 inches long and has a wing span of 74 feet. Its two engines are 550-hp., supercharged Pratt & Whitney "Wasps." On a coast-to-coast flight, these engines consume 900 gallons of fuel oil or an average of 3 gallons per mile.

COMPRESSED AIR AT WORK

The thousands of rivets in each all-metal plane are driven by air-operated tools. This picture shows a portion of a low-wing, twin-engined bomber, of which Boeing is constructing seven for the United States Army.

The Petroleum Engineer.

Rear end of a Deep Rock Oil Company Truck with the sliding brackets protruding from either end of the pipe that serves the double purpose of protecting the tail lights and the truck bed from damage during loading.

Detail of the guard and tail light (insert) in position for driving. When not in service the bracket is housed in the pipe within which is a track along which it slides. A bolt holds the bracket in place so as to prevent shifting.

Tail-Light Guard for Trucks

THERE is a good reason why heavy trucks traveling our highways at night are lit up more or less like Christmas trees. The innumerable red and green lights which they carry indicate to traffic the length of each vehicle, its height, and, what is still more important, are a warning to the motorist coming up behind that he has to be on his guard. To him the tail lights are as vital as the head lights are to a car approaching from the opposite direction, and perhaps more so because he has less chance to avoid a collision when suddenly confronted with an unlighted or poorly lighted conveyance.

Most states now impose a heavy fine on automobiles, and especially on trucks and buses, that are deficient in the matter of warning lights, and this explains why vehicles engaged in the business of transporting passengers and goods run over the roads after nightfall almost gayly illuminated. Aside from the primary consideration of safety, fines cost more than lights even though breakage may be high and replacement sometimes troublesome. This is especially true of trucks that are loaded and unloaded from the rear where the tail lights are usually so placed that they can be damaged or shattered easily by heavy obstacles. Such, at least, has been the experience of the Deep Rock Oil Company, which has overcome the difficulty by means of a simple device that protects those lights when they are not required. All its motor vehicles are now equipped with this improvised safeguard, which may interest other truck operators because it effectually does the work for which it was designed and greatly lessens the danger of being caught in transit with tail lights "out."

As described by E. L. Bell, superintendent of motor transport and machine shops of the Deep Rock Oil Company, the device consists primarily of two metal brackets each carrying a tail light, and of a length of 5 3/16-inch iron or steel pipe that is attached to the rear end of the truck bed and houses the brackets when the lights are not needed. Because oil-field trucks are required to haul heavy machinery, it is fairly common practice to protect them with piping as just described in order to prevent the wooden bed from being splintered or broken during loading. Inside of the pipe are secured two long metal strips forming a narrow slot or track in which the brackets slide in or out just far enough to be within easy reach of the driver or to show the lights plainly. Bolts hold the brackets in position when extended. Mr. Bell is responsible for the design and the arrangement of the tail-light guard.

Driving Forty Miles of Pipe Piles for One Foundation

L. F. BOOTH*

COURT HOUSE AND GENERAL VIEW OF SITE

Looking southwest upon the excavation at the beginning of pile driving on March 1, 1933. At the upper left is St. Andrews Church, the only structure to retain its place in the newly formed block. Beyond the church is visible the lower part of the Municipal Building whose foundations were sunk with the aid of pneumatic caissons. In the center background is the old New York Post Office which is soon to give way to a modern structure. The far wall of the excavation at the right shields the East Side Interborough Rapid Transit Subway. Architect's drawing (right) of the imposing United States Court House that will occupy the site and become an integral part of the city's civic center. The structure was designed by Cass Gilbert, Inc.

MORE than 4,000 pipe piles of 12-inch and 16-inch diameter and of lengths ranging up to 135 feet were driven in 90 working days on a site in congested downtown New York. Such is the outstanding achievement among many interesting and unusual ones marking the placing of the foundations for the new United States Court House. The work was done by the George J. Atwell Foundation Corporation of New York. All told, about 40 miles of tubular steel was hammered into the ground. Filled with concrete and capped by piers of the same material, these metal sections constitute so many sturdy stilts extending down through unstable ground and embedding themselves in the more solid material beneath. Upon them the structure which will soon rise virtually out of the shadow of the Municipal Building will impose a dead load of 37 stories of steel and granite. The placing of these piles in such a short space of time was made possible by developing pile-driver production to an extraordinary degree and by a fine adjustment between this key operation and the essential correlated operations of preparing the driving spaces, unloading and distributing the pipe, and placing the concrete in the piles and pier caps.

*Field Engineer, George J. Atwell Foundation Corporation.

Sharing only with old St. Andrews Church a newly formed city block of irregular shape bounded by Pearl Street, Foley Square, Park Street, Duane Street, and a new thoroughfare to be called Cardinal Place, the Federal Court House to be superimposed upon these piles will become an integral part of New York City's gradually developing Civic Center. The building will occupy a ground area of 72,800 square feet. On approximately 80 per cent of this plot the structure will rise to a height of eight stories, but the remainder will have to sustain a tower 37 stories or 562 feet high. It was possible to secure adequate support for the lower part of the building by driving piles in strategically located clusters and capping them with concrete to form individual piers of varying sizes and shapes. The greater weight of the tower, however, called for a concentration of piles beneath it. Accordingly, one vast pier, or mat, was created there. This mat covers an area of 14,500 square feet.

The site, itself, is steeped in the traditions of the old Dutch city of New Amsterdam from which the modern metropolis has sprung. In the days when debutantes wore hoop skirts and when Canal Street was "away up town," it adjoined what was known as the Collect. This was a pond from which the burghers once derived their water supply. All around it was low, marshy ground traversed by a meandering stream or two. All this area, including the plot under description, was filled in long ago, and during the intervening years has been built upon, the buildings demolished, and others erected in their places an uncertain number of times. At least one of the structures just razed was placed there as recently as 25 years ago.

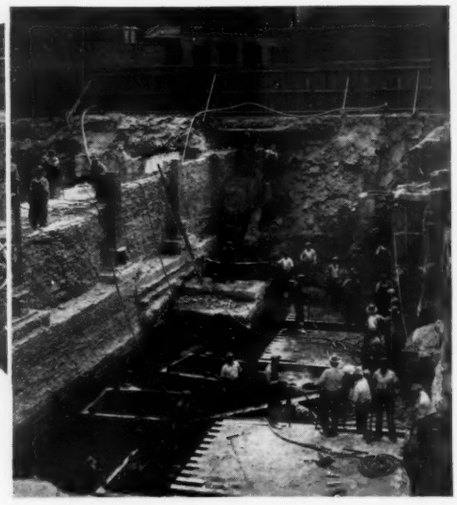
Bedrock in this area is at a depth quite beyond reach by any practicable method. When the foundations for the nearby Municipal Building were excavated in 1910, more than 100 pneumatic caissons were sunk to an average depth of 145 feet below curb. They still hold the depth record for this type of work in New York City. Since that time caisson work has been largely supplanted by the hollow-pile method of foundation support. The new system has several advantages, foremost among which are lower cost and greater speed.

Borings at various points on the site of the new courthouse indicated that the subsurface was composed largely of moderately coarse sand extending as far as 180 feet below street level. Distributed irregularly through the sand were occasional zones of gravel and bowlders. The preliminary investigations convinced those in charge that friction piles would best meet the existing conditions.

In addition to its unfortunate geological

TROUBLESOME ROOTS OF OLD STRUCTURES

When the workmen clearing the site delved beneath the street level, they encountered a miscellany of old foundation structures some of which stubbornly resisted their efforts. These pictures give a hint of the difficulties presented by masonry, metalwork, concrete, and piling. Paving breakers and "Jackhamers" demolished the concrete and loosened the masonry, thus exposing billets, grillages, and girders so that they could be burned through with torches and into pieces of a size suitable for removal. In some sections, as one of the views shows, wooden piling was uncovered, and this had to be extracted preparatory to driving the steel piles for the new building.



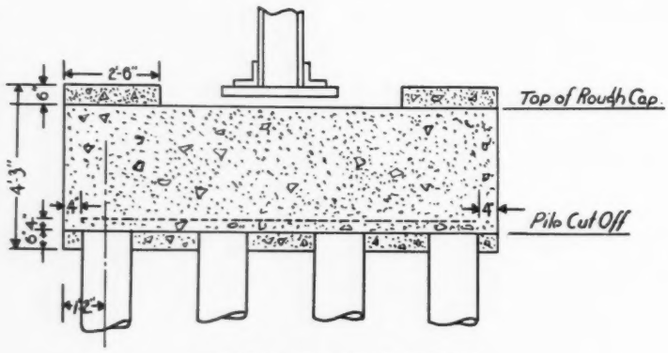
aspect from the foundation-design point of view, the site presented, at the very outset of operations, problems uncommon and troublesome from the construction standpoint. Threaded beneath one portion of it were subway ducts housing high-tension cables. These were not only of uncertain location but, what was more ticklish still, of uncertain degrees of liveness. It was known that serious damage, including the tying up of subway operations, might result if a drill steel, a clamshell tooth, or a shovel dipper should be accidently plunged into one of these ducts. In the face of this rather precarious situation, work of necessity had to be conducted with extreme care and delicacy.

A 4-foot sewer in an abandoned street which had formerly run through the site had to be maintained in service for six months while a new line to replace it was being built in another street. Last, but not least, the foundations of the buildings which had formerly occupied the site had to be removed. Of these subsurface structures, the worst proved to be that of the Board of Health Building, of brick and steel, which had stood upon wood-pile foundations in the northwest corner of the plot. These foundations were unusually heavy because, in addition to the ordinary billets and grillages, they contained a series of cantilever box girders 5 feet deep and concreted in. After the masonry walls and structural-steel members below street level had been blasted and burned away, these concrete-encased grillages and girders, the pile caps, and the piles, themselves, had to be removed. The masonry walls and pile caps presented no great problem, and were readily broken up with paving breakers and occasional light charges of powder placed in holes drilled with "Jackhamers." The grillages and girders offered more stubborn resistance, however, and had to be torn apart by the slow and tedious process of chipping away the concrete with paving breakers and then burning through the girders and reinforcing steel as soon as large enough areas were exposed. During these operations the air for the drills and paving breakers was furnished by two Ingersoll-Rand Type XL portable compressors.

The extraction of the old wood piles was necessarily slow and laborious and, wherever possible, was carried on at night. The piles were pulled out with a Vulcan pile extractor. They ranged from 20 to 25 feet long; and, because the natural ground-water level was somewhat above their tops, most of them were found to be in a fair state of preservation. But this was not always the case. Occasionally, a less sound one snapped off where the slings gripped it, which meant excavating around the remaining stump to secure a better hold on sounder wood lower down.

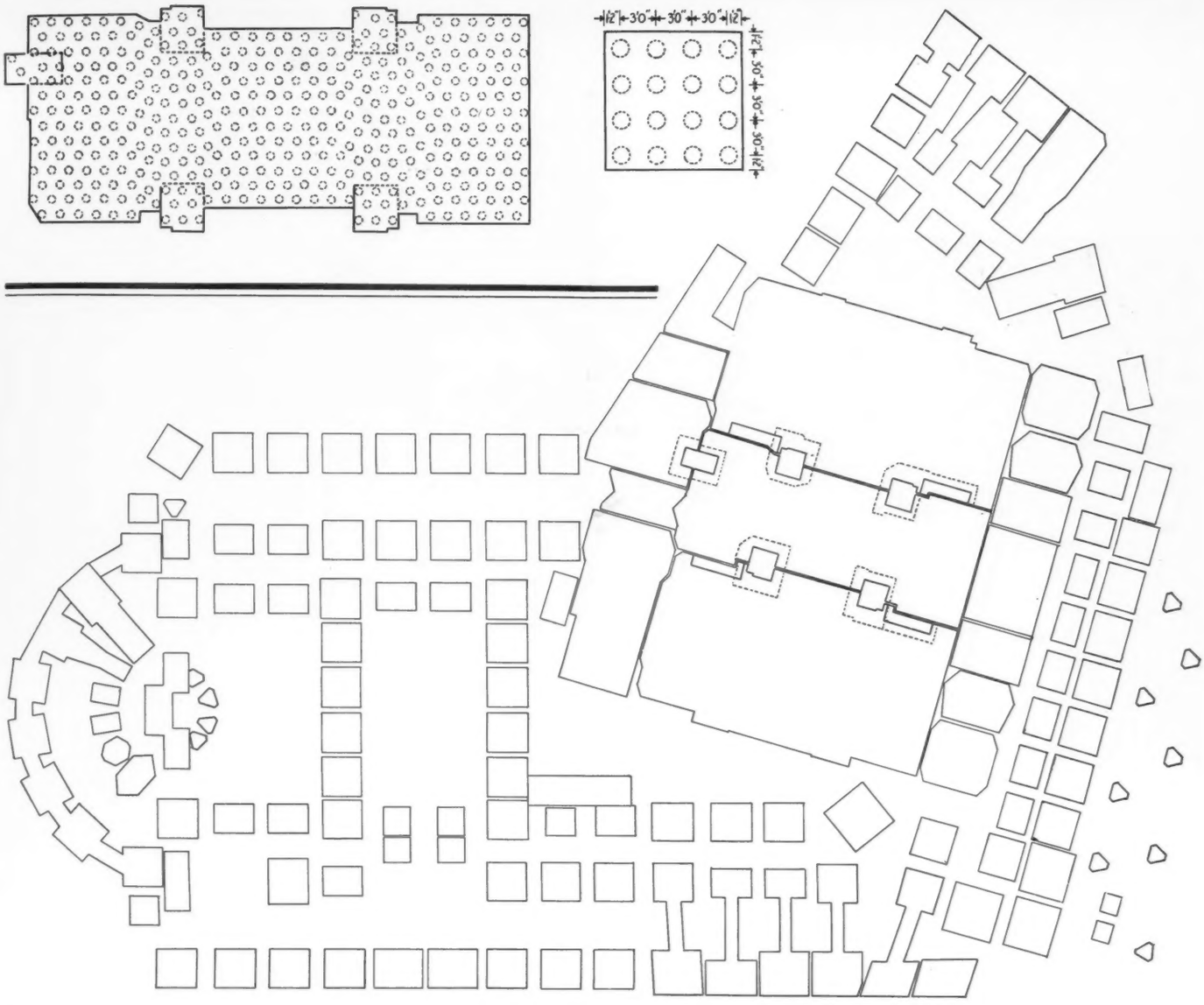
In the eastern part of the site a surprise package in the form of massive foundations of an old power house, that had been buried under 8 feet of earth fill some time past, greeted the shovels as they dug in. These proved to consist of several thousand cubic yards of solid masonry which required drilling and blasting to reduce it to sizes that could be handled. Later on, a note of humor was introduced by the workers in the southwest end of the area when, upon removing the furring or external sheathing from the brick wall of what had been St. Andrews parish house, they uncovered a sign, in letters 3 feet high, which read: "Bonded Warehouse—Liquors—Wholesale and Retail—Brandies." Investigation revealed that, prior to its use as a parish house, the building had served first as a schoolhouse and later as a saloon. While these various obstructions were being disposed of, a Bucyrus-Erie 21-B shovel was occupied with the removal of 23,000 cubic yards of earth from the open sections of the area in order to bring them down to grade.

Pile driving was started as soon as sufficient space was cleared to permit it; but before many of them had entered the ground it became apparent that the foundation as designed—consisting of 12-inch pointed pipe



TYPICAL FOOTING DETAIL

How the piles are cut off at the same level, filled with concrete, and then capped with concrete to form a pier for the support of the steelwork.



PLAN OF FOUNDATION WHERE 4,000 PILES WERE DRIVEN

Each of the enclosed areas represents a concrete pier consisting of varying numbers of 12- or 16-inch hollow steel piles driven to depths as great as 135 feet. Upon the major portion of the site, as indicated by the individual piers, the court house will rise to a height of eight stories, while the large area at the upper right will support a 37-story tower. Although the concrete throughout this section was poured in three separate forms, as shown by the double dividing lines, this is, in effect, one great mat, and the piers at either side of it are so closely spaced that they may be considered parts of it. The total area of the plot is 72,800 square feet, of which the mat takes up approximately one-fifth. The dotted lines indicate elevator pits. At the upper left are two sketches showing typical arrangements of piles. The smaller diagram is the plan of the pier at the extreme left of the bottom row in the main drawing. The other represents the central portion of the mat. It is approximately 37 by 88 feet in dimensions and contains 374 piles. More than 1,000 piles were driven in the three mat sections.

piles, 30 feet long, set in clusters under the individual piers and *en masse* in the mat beneath the tower—was not well adapted to the soil conditions and would have to be modified. Instead of "fetching up" at depths of around 30 feet, the piles did not attain the required hammer refusal until lengths of from 60 to 90 and even 100 feet had been sunk. Accordingly, the driving was discontinued and a period of experimentation begun. In order to determine more definitely what was needed, pipe piles of 12-, 16-, and 18-inch diameter, Raymond piles, and precast-concrete piles were sunk in various parts of the site and under varying conditions. After being driven, each of the several types was inspected and then tested under a dead load of from 60 to 110 tons, depending upon its settlement as the load was applied. It was concluded from these operations that the problem could be solved best by using 12-inch and 16-inch pipe piles—the size to be employed at any one point throughout the site being determined by local conditions.

After this decision had been made, driving was started in earnest. Four rigs were set up for this purpose, all equipped with leads which permitted them to handle piles 50 feet long. Two of the rigs were standing or stationary units, which were moved about as desired by derricks. These standing leads are a departure in pile-driving equipment and were developed especially for this job by the George J. Atwell Foundation Corporation. They proved to be efficient and mobile units. By arranging the sills in advance, the moving time, and hence the time lost in actual driving, was reduced to a minimum because that made it possible simply to lift the leads off the finished pile and to set them up over the location for the next pile. The guys for holding the leads erect were adjusted while the new pile was being swung up into position for sinking. Each of the other two rigs was attached to a Loraine 75-B crane, which enabled shifting it about as required.

The success of the standing leads and the facility with which they lent themselves to

HERE AND THERE ABOUT THE BUILDING SITE

During the preliminary investigations, in determining the kind of pile that would best suit certain conditions, loads as great as 100 tons were imposed upon individual piles by means of equipment especially devised by the Atwell organization. Above, right, is shown one of the forms in position for testing. Throughout the foundation work, piles were taken at random and subjected to loads ranging from 30 to 60 tons. The two Type XL portable compressors (above) which supplied air for the demolition of the subsurface structures of the buildings that had occupied the site and which also formed a part of the compressor plant used by the contractor during the pile-driving operations. Close-up of one of the mobile pile drivers (bottom right). It was moved about by the Loraine 75-B crane to which it was attached. These as well as the stationary units were tall enough to permit the handling of 50-foot piles.

the work in hand proved very helpful in keeping operations moving at a good rate. On a foundation job of this kind, progress—that is, the economic conduct of the entire work—hinges upon the pile driving. The aim of the contractor is to keep the hammers hitting nearly 100 per cent of the time. It is, of course, impossible to reach this ideal performance; but it can be approached if all phases of the pile-driving operation are well organized and closely synchronized. Happily, these requirements were met satisfactorily by the Atwell organization, with the result that the four driving rigs were pounding away at the piles well-nigh continuously.

In the case of the isolated footings, with relatively few piles, the latter were driven with moderate ease until refusal penetration was approached, and then brought up fairly quickly. However, in the mat area, where the piles were more numerous, the ground became more compressed with the sinking of each succeeding pile and, before many of them had been put down, the resistance was so great that the piles drove harder almost from the start than they did normally near the finish. Indeed, this condition became so accentuated that some piles were driven for distances of 15 to 20 feet at a rate of penetration no greater than 1 inch for every 20 to 30 blows.

The minimum pile length permitted under the specifications was 15 feet. Ordinarily, after having been driven to that depth, a pile was considered to have met proper refusal when from three to four blows were required to drive it 1 inch. Based on the *Engineering News-Record* formula, as applied to the hammers in use, this resistance indicated that the pile could be safely loaded with 35 tons.

Four Warrington-Vulcan, No. 1, single-acting hammers were used for driving. The weight of the ram, or striking member, was 5,000 pounds, and the minimum stroke or distance of travel in the leads was 3 feet. The rated operating speed of these hammers is 60 blows per minute, and they met or exceeded this rating consistently. Both steam and compressed air were used for driving, with air predominating. Each hammer required 975 cubic feet of air per minute at 80 pounds pressure. The same two Type XL compressors that were employed during the clearing of the site were included in the contractor's air plant on this job.

The piling consisted of electric-welded steel pipe with 3/8-inch shell manufactured in the Youngstown plant of the Republic Steel Company. Save for a few shorter sections, they were delivered at the site in lengths of from 40 to 55 feet. To enable their driving without filling up, the piles were fitted with cast-steel driving points. The flanges on these, as well as the sleeves used to connect the sections when more than one length of pipe was needed, were made tapered and slightly oversize

A PIER AND THE PILE-DRIVING EQUIPMENT

The piles in each pier (upper left), depend upon friction rather than bearing for their support giving properties, as bedrock in this area is 180 feet below street level—too deep to be reached. The piles were generally driven on 3-foot centers and cut off when they reached the refusal point. This picture also shows the type of point affixed to each pile to prevent its filling with dirt and to facilitate driving. At the height of the pile-driving operations (above), showing the two stationary and the two mobile rigs or leads that were used for this work. As a result of thorough preparation and effective organization the hammers were kept going almost continuously. Close view (left) of one of the four hammers in action. These Vulcan No. 1 units have a 2½-ton hammer and strike a minimum of 60 blows a minute. They can be operated either with steam or compressed air. On this job most of the pile-driving was done with air.

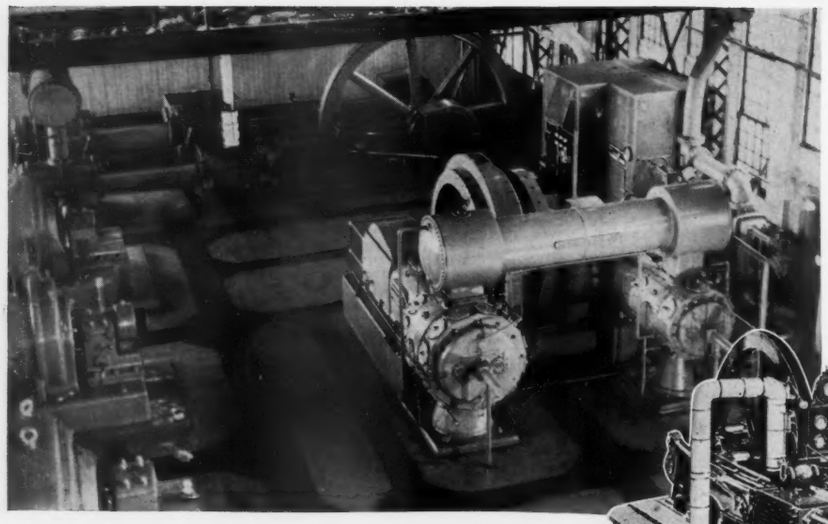
in an effort to secure watertight joints.

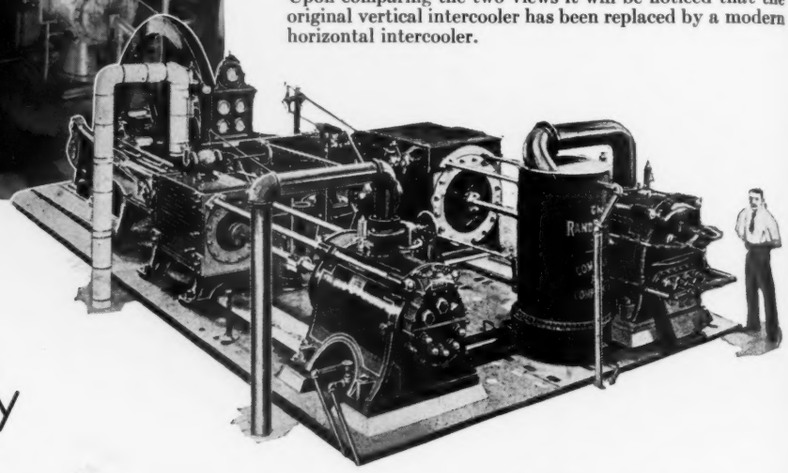
As soon as a pile had been driven to the required penetration, as indicated by its resistance to hammering, it was burned off at the proper height by an oxyacetylene torch. When a cluster of piles making up a pier, or a group of piles in the mat, had been driven, the pipes were filled with concrete. Occasionally, where a joint had become leaky, or where the cut-off elevation was below ground-water level and for some reason temporarily submerged—as was the case in the elevator-pit areas—it was necessary to remove the water from the pipes before placing the concrete. At first this was done by blowing with compressed air; but later on, in order not to deplete the air supply and thereby interfere with hammer operations, other means were decided upon. Various pumps were tried and several of them proved satisfactory in pipes as deep as 70 feet. For pipes of greater depth no suitable pump could be found that was small enough to be inserted in a 12-inch pipe, and, accordingly, the Atwell Company devised a pump for use in the deeper piles that did the work successfully.

Concrete for filling the pipes and, later on, for pouring the pier caps and the mat was prepared in Ransome 1-cubic-yard paving-type mixers which were moved about the site and kept close to the areas of pouring. Sand and gravel were delivered in batch trucks and dropped directly into the mixer pans; and cement was also trucked to the points of use. Altogether, about 7,000 cubic yards of concrete was placed in the pipes and 7,500 cubic yards in the pier caps and the mat. The largest pours were those for the three mat sections, two of which required 1,400 cubic yards and the third 1,000 cubic yards. No records were established during the concreting operations, as the work was done under strict Government specifications relative to mixing time, materials used, and manner of placing.

As can be seen from the architect's drawing on the first page of this article, the building that will rest upon these piers will be an imposing one, even in a city that is known for its many fine examples of the builder's art. The completed structure will represent an expenditure of approximately **$8,000,000.** Following the partial clearing of the site, ground was formally broken on July 20, 1932. It is expected that the building will be ready sometime during 1934. It will serve as a center for Federal Court proceedings and will provide offices for the Government judiciary.

This interesting foundation undertaking was carried on by the Atwell Company under the direction of George V. Salle, George Blackmore, chief engineer, and George S. Kelley, mechanical engineer. Nels Hansen, as resident construction engineer, represented the Supervising Architect's Office of the U. S. Treasury Department. The building was designed by Cass Gilbert, Inc.





JUSTIFYING ITS BLUE RIBBON

The Rand steam-driven compressor in the background of the picture at the left won first prize at the 1893 Columbian Exposition in Chicago and has since proved its right to that honor by supplying air for the mining of more than 16,000,000 tons of coal at the Caledonia No. 4 Colliery of the Dominion Coal Co., Ltd., in Nova Scotia. It is still operating almost continuously. In front of it is a modern synchronous-motor-driven compressor which produces more than two and a third times as much air but occupies considerably less floor space than the veteran. The lower picture is from an old print and shows the 1893 compressor as it looked at the World's Fair. The air cylinders are at the near end and the steam cylinders in the center. Upon comparing the two views it will be noticed that the original vertical intercooler has been replaced by a modern horizontal intercooler.

Prize Compressor of 1893 Still Runs Steadily

AT A TIME when the Century of Progress International Exposition is in full sway at Chicago, it is of interest to note that at least one machine exhibited at the previous Chicago World's Fair held 40 years ago is still operating efficiently. The machine referred to is a Rand Type BB-3 air compressor now in service at the Caledonia No. 4 Colliery of the Dominion Coal Company, Ltd., at Glace Bay on the northeast coast of Cape Breton Island, Canada.

This old compressor has made a formidable record for itself. According to officials of the company that owns it, the unit has furnished air for the mining of 16,138,650 tons of coal. It is estimated that since its installation, in 1895, it has been running approximately 75 per cent of the time, day and night. A computation on this basis indicates that its aggregate running time has reached the amazing figure of 248,565 hours. Even more significant than this is the report that it is now operating virtually 24 hours a day and that it is in good general condition.

The machine antedates the era of electrically driven compressors. It is driven by a cross-compound condensing Corliss engine. It is a 2-stage unit of the duplex type and of the same general design that characterized all compressors of the period in which it was built. A distinguishing feature of these rather ponderous machines was a heavy flywheel located centrally between and at one end of the tandem cylinders. The two cylinders nearer the flywheel on either side were for steam, and beyond them and connected to them by piston rods were the two air cylinders. Those units were far heavier than modern compressors of equivalent capacities. They likewise took up several times as much floor space and required heavier and more extensive foundations.

The Caledonia compressor has steam cylinders that are 40 and 22 inches in diameter and air cylinders of 34 and 22 inches, the stroke in both cases being 48 inches. It has a capacity of 3,000 cubic feet per minute. It is equipped with mechanically operated valves of the poppet type.

This venerable compressor was built in New York City in 1892 by the Rand Drill Company, which was subsequently consolidated with the Ingersoll-Sergeant Drill Company to form the present Ingersoll-Rand Company. The machine not only was exhibited at the Columbian Exposition at Chicago in 1893, where it received first award in its class, but also was put to work there providing air for use in Machinery Hall. Thus, in addition to its coal-mining service, it has to its credit an unrecorded number of hours at the exposition.

The prize compressor was purchased by the Hon. David MacKeen, who, in addition to occupying a prominent place in the coal-mining industry, held numerous public offices of trust and was lieutenant-governor of Nova Scotia at the time of his death in 1916. He was general manager of the Dominion Coal Company in 1893 when he attended the Chicago fair. He bought the machine and ordered it shipped to Glace Bay. Some two years were consumed in building a new power house and in erecting the compressor; and, accordingly, it was not placed in operation until September, 1895. It was installed by John A. Fergusson, then colliery engineer and at present district master mechanic with supervision over this and other of the company's collieries in the same area.

The original steam cylinder rods are still in the machine. The low-pressure steam cylinder was rebored and the piston fitted with new rings in April, 1923, and the same operations were performed upon the high-pressure steam cylinder in January of 1927. The low-pressure air cylinder was relined in March, 1923, and the high-pressure air cylinder underwent like treatment in August, 1925. Except for these items the only attention the unit has received has been an annual overhauling. Charles Ross, chief clerk in the mechanical office of the Dominion Coal Company, Ltd., states that it is in good, serviceable condition at the present time.

Caledonia Colliery No. 4 has been producing coal since 1866, and it is the fourth oldest property among those comprising the Dominion Coal Company. It operates on what is known as the Phalen Seam, and for some years past all the coal derived from it has been taken from underwater areas. The current output is around 1,950 tons a day, and 600 men are employed.

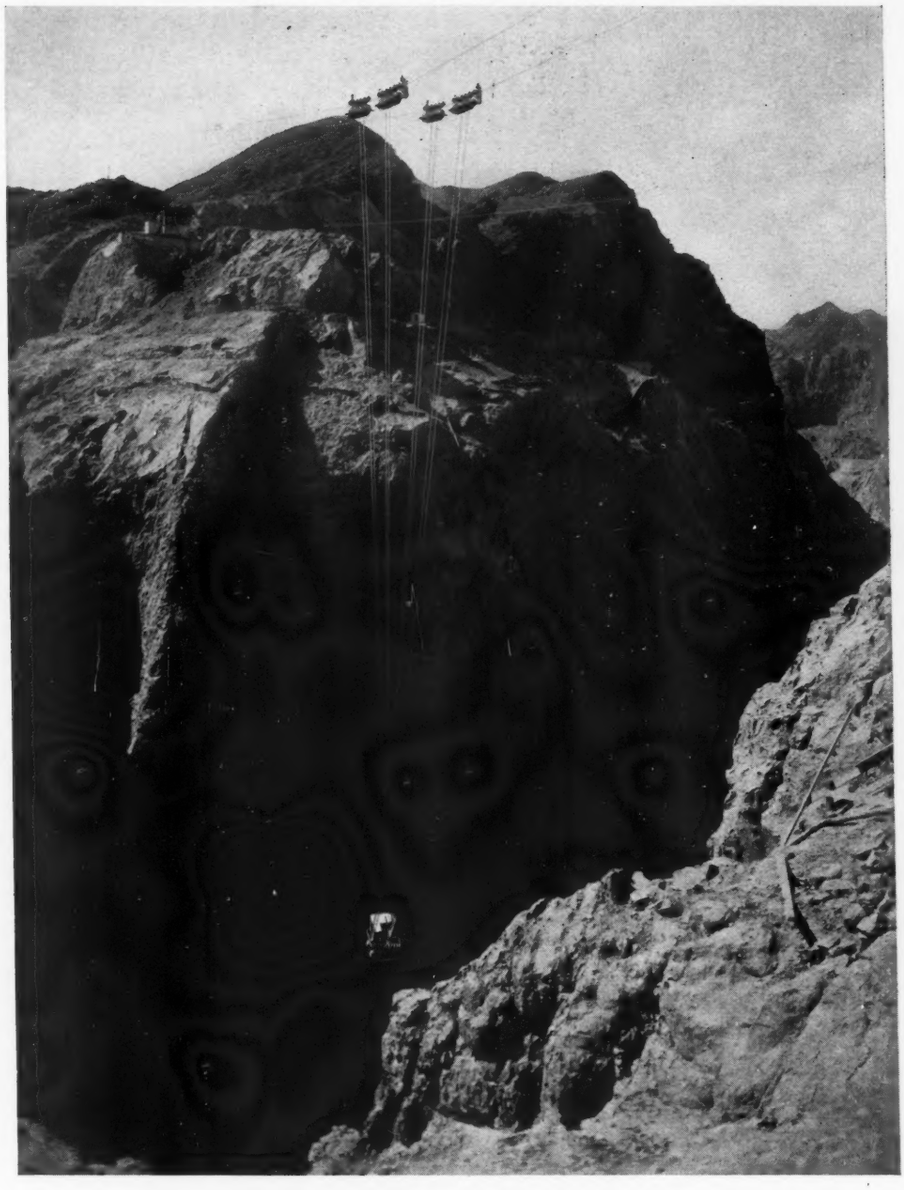
The mine is worked through a hoisting shaft 185 feet deep. Steam is the primary source of power; but some machinery, including the main pumps which raise water from underground to the surface, are electrically driven. The coal is all cut by air-operated Rand "Radialaxes" and "Jackhamers." There is now in service in the colliery 41,600 feet, or approximately eight miles, of endless haulage rope 1¼ inches in diameter.

In addition to the World's Fair compressor, Caledonia Colliery has another compressor whose age is sufficient to command respect. This is a steam-driven Canadian Ingersoll-Rand unit, with a capacity of 2,500 cubic feet per minute, which was installed in 1900. It, too, is pronounced to be in first-class condition. Together, the two compressors have been on the job 71 years and give promise of remaining serviceable for some time to come.

Construction of the Hoover Dam*

A Description of the Tunnels for the Penstock Headers, the Penstocks, and the Canyon-Wall Outlets

RUSSELL C. FLEMING



DOWN SHE GOES!

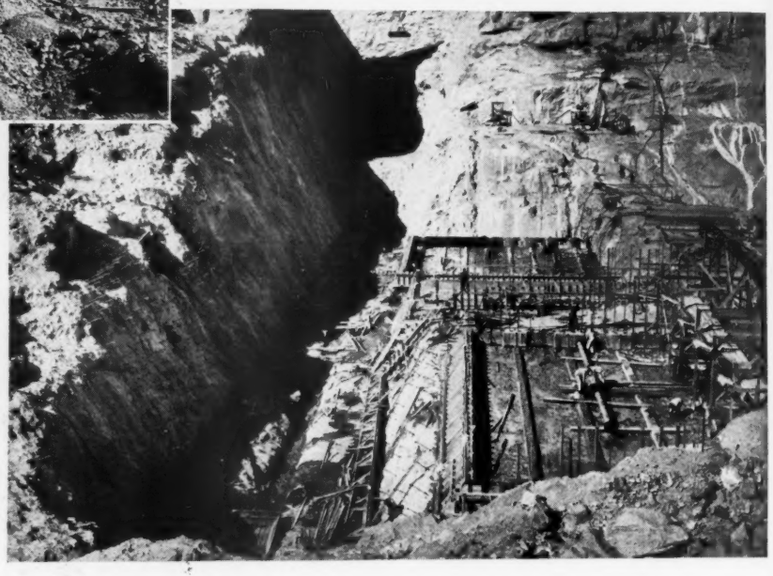
A previous article in this series described the aerial transport system that spans the canyon to facilitate the movement of men and materials. Here we see a complete Bucyrus-Erie 43-B power shovel being lowered into the abyss by means of two of the 20-ton cableways working in unison.

OPERATIONS at the Hoover Dam have reached an important transition period. Until the spring of this year efforts had been directed mainly towards works in connection with the diversion of the river or otherwise preliminary to the construction of the dam, itself. Now most of those preliminaries have been executed and activities are centered on the permanent features of the project—those that are necessary for the generation of power and for the control of the Colorado during flood periods, those at which tourists will marvel and which they will photograph for many years to come. The transition is not sharp. It cannot be said that the preliminary operations were finished one month and construction on the dam and the other permanent features begun the next, for much of the work is necessarily interrelated. Too, some of the work already completed will be converted later and become an integral part of the final structure. The first phase is just merging gradually into the second and more enduring phase.

During the late spring of 1933 there was a change in the scene of activities, and the contractors then took up the work in which they are now principally engaged and which includes the following: excavation of the river bed for the dam foundation; final trimming of the canyon walls where the dam abutments will rest; pouring concrete for the spillways; excavation for the intake towers; driving the tunnels for the penstock headers, the penstocks, and the outlet works; finishing the 150-ton cableway which will be permanent and which will be used during the building period primarily to convey the heavy power-house machinery and the pipe sections for the penstocks from the top of the canyon to the river bottom; and finishing the construction of as well as equipping the plant of the Babcock & Wilcox Company in which will be fabricated the enormous sections of pipe for the penstock headers, the penstocks, and the outlets.

A comprehensive view of the whole project is necessary in order to understand the part that these works will play after the dam is completed. A brief sketch, previously published in these pages, is therefore given again so that it will be easier to follow the operations now in progress. When the dam is finished and the reservoir filled, some provision must be made to allow excess water to escape to the river channel below. Some of the water will course through the turbines—expending its force in generating electric power and then discharging into the tailrace. Means are also being provided for water to by-pass the turbines and to flow into the stream bed. In addition to this, however, spillways are very necessary at the top of the dam to permit the escape of the excess of inflow over outflow. In the usual dam construction the spillways are built in the top of the dam or in the wings, and an open channel, carefully contoured, carries the water which overflows the spillway weirs to the river channel below.

**Fifteenth of a series of articles on the Colorado River and the building of Hoover Dam.*



DRILLING THE SPILLWAYS

The digging of the spillways on either side of the river involves the removal of 580,000 cubic yards of rock. For placing the accessory structures there will be required 110,000 cubic yards of concrete. Each spillway will connect, through an inclined tunnel, with the outer 50-foot diversion tunnel on its side of the river, thereby making possible the by-passing of 400,000 cubic feet of water a second should this ever become necessary as the result of a flood of sufficient volume. At capacity, the discharge from each spillway will be equal to the normal flow over Niagara Falls, and the total drop will be more than three times as great. The energy of the falling water will be about 25,000,000 hp. The picture at the upper right shows "Jackhamer" men starting the excavation for the Nevada spillway. Below is a view of the upstream portion of the weir foundation in this spillway as it appeared several months later. Above this legend is the excavation for the Arizona spillway as it looked on April 21, 1933.

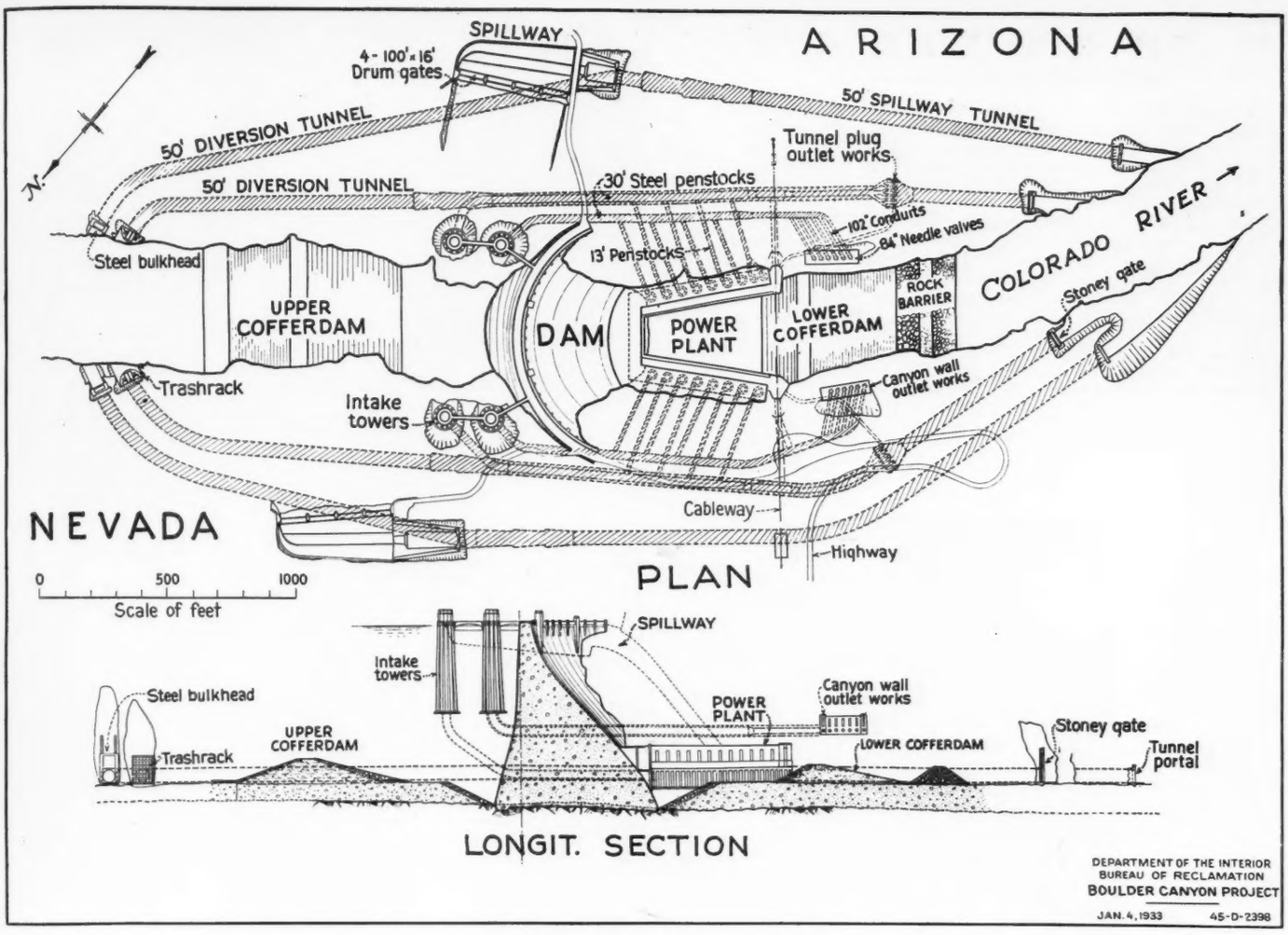
In Black Canyon a slightly different plan is being followed. Two spillways are being constructed, one on each side of the dam. The weirs and weir channels are set high up on the rocky walls of the canyon with the crest of the weirs paralleling the course of the river. Large excavations were made in the solid rock of the walls for these spillways. The concrete-lined open channel behind each crest will be approximately 650 feet long, 150 feet wide, and 120 feet deep, and from these channels the water of the two spillways will be discharged through the two outer diversion tunnels. Water from the Nevada spillway will discharge down an inclined tunnel into the outer (No. 1) diversion tunnel on the Nevada side and the spillway on the Arizona side will discharge similarly into the outer (No. 4) diversion tunnel on that side. Thus portions of each of two of the diversion tunnels will become permanent spillway channels when the time comes.

It is estimated that 110,000 cubic yards of concrete will be used in the spillway works—28,000 in the channel linings and the rest in the weirs, and a total of 580,000 cubic yards of rock has been excavated for the two spillways. The weirs on each side will be about 450 feet long, with an effective length of 400 feet. Each weir will be topped by four 100x16-foot drum gates. Behind the weirs the open channel will slope downstream on a 12 per cent grade to an overflow weir, 35 feet high, and then connect with the inclined tunnel leading down to the diversion tunnel. The inclined tunnel will be 50 feet in diameter (the same as the diversion tunnel) where the two tunnels join and, as the incline rises, will expand first to 60 feet and then into a section with a 3-center top arch of 80-foot span. The lower part of the incline is laid on a parabolic curve, and involves precise office and field engineering.

On both sides of the canyon the work of excavating for the weirs and open channel was completed by the first of May, and forms were being placed for the concrete lining. On the Nevada side the inclined tunnel was excavated but not yet lined with concrete, and on the Arizona side a 7x14-foot pilot raise had been driven through to connection with the diversion tunnel. When the outer diversion tunnels are no longer needed for diversion purposes, each will be stoppered with a solid concrete plug about halfway down its length and just above where it connects with the spillway tunnel. The diversion tunnels are enlarged at that point and the plugs, 400 feet long, will be firmly anchored in the solid rock. The course of the outer diversion tunnels was purposely laid so that those tunnels could be made a part of the spillway structures.

Of prime importance in the completed project will be the works that are designed to lead the water from the reservoir to the turbines in the power house. These will consist of four intake towers in the reservoir above the dam, of a penstock header leading from the bottom of each tower past the dam, and of four penstocks branching from each header. Each of the latter penstocks, excepting one, leads to a turbine in the power house. Also included in these plans are outlet works below the penstocks whereby the water may be made to by-pass the turbines and to discharge directly into the tailrace. At the present time the sites for the intake towers have been excavated and the tunnels for the upper penstocks, the penstock headers, and the outlet works are being driven. These tunnels will contain steel pipes fabricated from plate steel in the plant of the Babcock & Wilcox Company located 1½ miles from the dam site.

Description of the intake towers must be left to a later article, likewise the absorbing story of how the great pipes will be fabricated, transported, and placed. Of more immediate interest is the driving of the tunnels for this piping. As the power house is to be U-shaped, with one wing on each side of the river, and as each wing will contain half of the power-generating equipment, the penstock works will also be twinned and almost identical in each



GENERAL SCHEME OF OPERATION

These diagrams show the relationships between the various structures. Reference to them and to the drawing at the bottom of the last page of this article will enable the reader to follow the text understandingly.

canyon wall. A description of the layout on one side will therefore suffice for both.

A pair of similar intake towers will be built on each side. From each upstream intake tower is being excavated an inclined tunnel, 41 feet in diameter, to connect that tower with the inner diversion tunnel (No. 2 on the Nevada side and No. 3 on the Arizona side). Dropping directly from the bottom of the tower, this tunnel bends gently to form an incline and then, at the lower end, bends again to meet the diversion tunnel. The incline will be lined with 2 feet of concrete, giving a finished diameter of 37 feet, and through it and the inner diversion tunnel will be run the 30-foot steel pipe line connecting the tower with the penstocks and the outlet works. The diversion tunnel will be sealed just above the connecting point with a concrete plug 300 feet long. Provision was made for this plug in driving the diversion tunnel—the concrete lining, except for the arch section which was left unlined, being poured in conformity with the shape of the plug. In the meantime, wooden forms have been placed in the invert and sidewall sections so as to provide a continuation of the smooth inner face of the tunnel. These will be torn out when the plug is to be put in position. The plug will be approximately 65 feet in diameter at the widest point and will have three tapered shoulders whereby to anchor it to the tunnel wall. Thus the two inner diversion tunnels will also find employment in the ultimate structure.

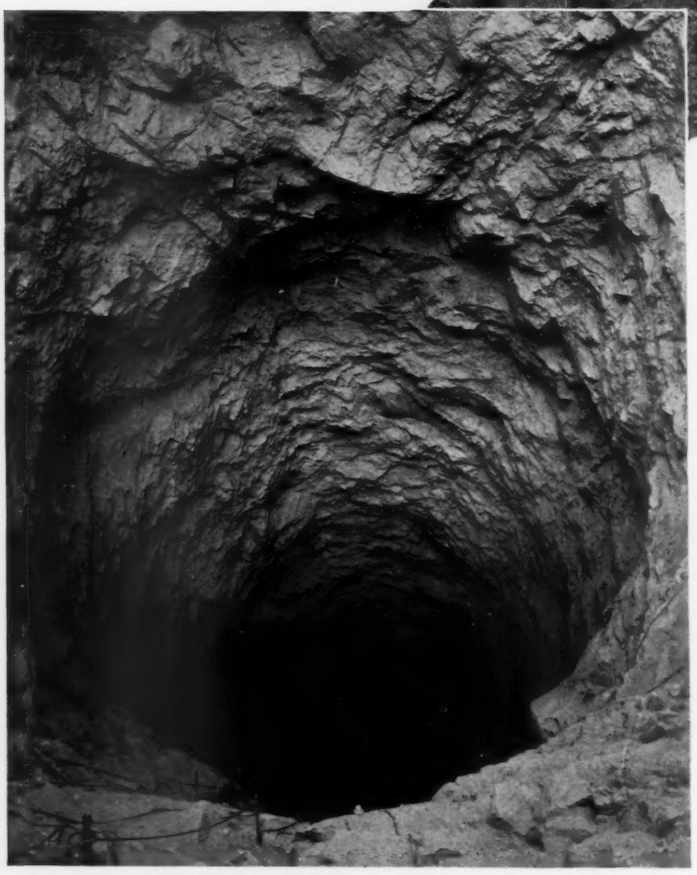
From each of the two downstream intake towers a header tunnel is being driven all the way to the penstock connections and beyond to the canyon-wall outlet works. This tunnel also is to be 41 feet in excavated diameter and to have an inside diameter, including the concrete lining, of 37 feet. To drive the tunnel and to admit the pipe sections it was necessary to run a construction adit 26 feet wide and 43 feet high from the canyon below the penstock tunnels, at elevation 820, to the line of the tunnel. On the Nevada side the header will be 1,322 feet long from the construction adit to the intake tower and require the removal of approximately 75,000 cubic yards of rock: on the Arizona side the tunnel will be 1,197 feet from the adit to the tower and require about 67,000 cubic yards of excavation.

Each of these 41-foot tunnels is being driven full face without the aid of a pilot bore by means of a huge drill carriage or jumbo which is mounted on wheels and which is moved on rails. This device, which makes it possible normally to combine as many as 20 drills in a concentrated attack upon the breast, is a modification of the type of carriage that was developed for driving the diversion tunnels and that was described in detail in an earlier article in this series. The carriage has three working platforms in addition to the ground level. Across its front are four horizontal bars, on each of which are mounted from four to six Ingersoll-Rand N-75 drifter drills. Compressed air is furnished by the established plant and delivery system and is fed through a 4-inch line to the piping on the carriage. A standard round of drilling, as illustrated in an accompanying sketch, is used at the tunnel face. The firing is done with delay primers. The normal rate of advance is one 12-foot round per shift. The rock is handled at the face by electric shovels and taken out of the construction adit in trucks. It is dumped on the canyon floor, picked up by another shovel, and hauled away. Part of the rock is used in the cofferdams and for construction purposes in the river bed. By May 1, the

WATERWAYS THROUGH ROCK

For a portion of their lengths the diversion tunnels next to and on either side of the river will serve as penstock headers, and from them the water will flow through four penstocks to the power turbines. The picture at the right shows one of these penstock tunnels being opened from within the lined interior of a diversion bore. A Conway mucking machine is at work.

Below is a view of the inclined spillway tunnel on the Nevada side while driving was in progress. This bore will carry excess water from the Nevada spillway to the No. 1 diversion tunnel. It was excavated by driving a top heading upward at an angle from the diversion tunnel. This pioneer opening was then enlarged until it was 14 feet wide and 56 feet high; and, as a final operation, the remaining material on either side was taken out to the full 56-foot circular section. This last stage, which is pictured, was carried on from the top downward, the muck being allowed to fall into the diversion tunnel from which it was removed for disposal.



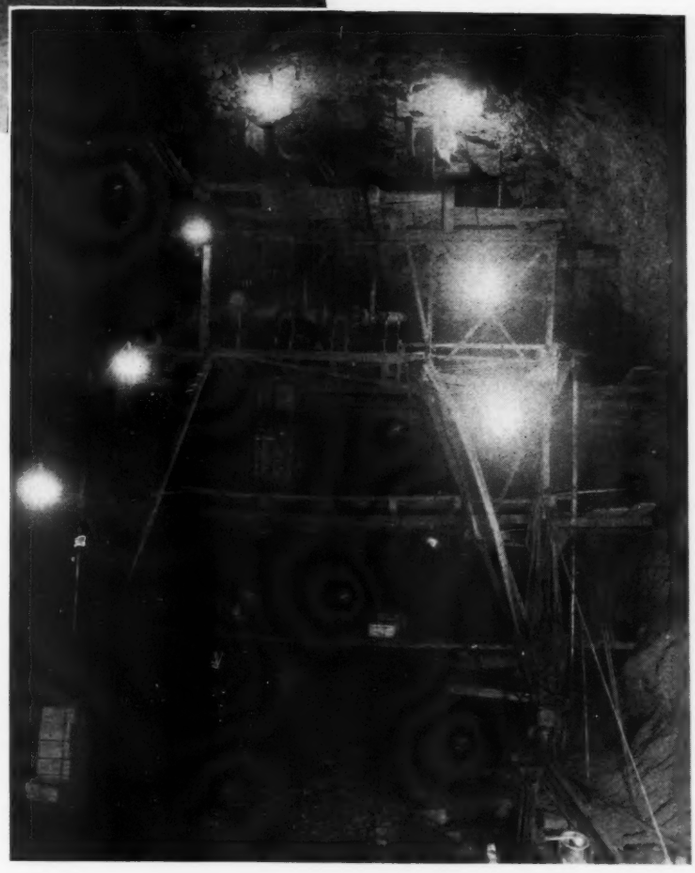
SHARPENING STEEL

Hundreds of tons of drill steel are being consumed at Hoover Dam. The reconditioning of drill steels is an important item in maintaining drilling progress. At the left is one of the many outdoor shops that have been set up for this purpose.

header on the Nevada side had been driven 695 feet and on the Arizona side 652 feet—each more than halfway.

These tunnels have no grade and are at elevation 820, considerably higher than the headers in the diversion tunnels. In the diversion tunnels the center line of the steel pipe will be approximately at elevation 649 where the penstocks take off, and the center line of the turbine runners in the power house will be about at elevation 637. Consequently, the penstocks from the upper headers will incline at a fairly sharp angle while the penstocks from the headers in the diversion tunnels will be almost flat.

Four penstocks will branch from each header, or eight from the two headers on each side of the river. These penstocks will reach the power house alternately—that is, Nos. 2, 4, 6, and 8 on the Nevada side will branch from the upper header and Nos. 1, 3, 5, and 7 will branch from the diversion-tunnel header. On the Arizona side the arrangement differs in that Nos. 1, 4, 6, and 8 will come from the upper header and Nos. 2, 3, 5, and 7 will extend from the diversion-tunnel header. The penstock tunnels are being excavated 21 feet in diameter and will be 18 feet in diameter after the concrete lining is in place. Each penstock pipe will be 13 feet in diameter. The Nevada penstock tunnels from the upper header will have an aggregate length of 1,373 feet and will require the excavating of 17,600 cubic yards of material, and the four from the diversion-tunnel header will be 1,473 feet long and 18,900 cubic yards of rock will be removed from them. The Arizona tunnels from the upper header will have a total length of 1,348 feet and involve the excavating of about 17,300 cubic yards, and those from the diversion-tunnel header will be 1,356 feet long and will call for proportionately more excavating.



DRILL CARRIAGES

Tunnel driving at Hoover Dam has been notable for the development of huge structures which permit a number of drills to work simultaneously on a rock face. These carriages not only provide for concentrated drilling but save time in setting up and also facilitate moving the drills back from the face before blasting and returning them after mucking is completed. The accompanying views show two such carriages or jumbos used in connection with the penstock work. Below is a rear view of the rail-mounted structure employed in the 41-foot headers. The drills are mounted on four horizontal bars across the front, permitting as many as twenty machines to operate at once and making it possible to drill the full face (about 130 holes) without moving the carriage. At the left is a truck-mounted carriage of the type used in the flat tunnels leading from the diversion bores to the turbine sites.

All the penstock tunnels on the Arizona side and those from the upper header on the Nevada side are being driven inward from the canyon. Those from the diversion tunnel on the Nevada side were advanced from within the diversion tunnel before it was utilized as a watercourse. The flat tunnels are being driven by truck-mounted drill carriages equipped with fourteen N-75 drifters mounted on crossbars and operated from the ground and from three platforms. The normal rate of advance is one 12-foot round per shift. A round usually consists of 35 holes, and these are distributed over the face much as are the holes in the penstock-header round, which is illustrated. Eleven boxes of powder are ordinarily used per round, and 10 cubic feet of rock is excavated per foot of advance. A tunnel crew includes four miners, four chuck tenders, one nipper, one operator for the Conway mucking machine, one cable tender, two pitmen, and two truck drivers per shift.

The inclines to the upper headings are excavated by driving an 8x8-foot center heading and then enlarging this opening to full size by two ring drillings. The usual round in the center heading consists of eighteen holes, and the normal advance per round is 6 feet. The ring holes are drilled on 3-foot centers. The center headings are kept just ahead of the full face so that the same set-up will do for both. The muck is pulled down the incline with a Bagley scraper and loaded with a Conway mucking machine into trucks for disposal. The mucking machines are also used in the flat tunnels—one mucking machine serving two tunnels.

At the last report all the Arizona tunnels were in process of driving except No. 4, which was completed. On the same side the penstock tunnels to the lower header will be driven close to the diversion tunnel, only an adequate rock barrier will be left standing between

TUNNEL MUCKING

The 41-foot circular penstock headers on either side of the river were drilled full face with jumbos and the muck was loaded into trucks by electrically operated shovels. The picture at the right shows a Marion 450 shovel at work.

them in each case. These several barriers will be holed through and connections made later when water no longer flows through the diversion tunnel. The Nevada tunnels to the lower header were driven full length from within the diversion tunnel before water was turned into it, and were finished late last year. Arched, reinforced-concrete bulkheads about 16 inches thick and with a 20-foot radius of curvature were put in place to seal the openings before the diversion tunnel was used as a watercourse. Each of the penstocks will bring water to one 115,000-hp. vertical turbine in the power house except No. 8, downstream on the Arizona side. This penstock will split and will serve two units of 55,000 hp. each—the tunnel also being split into two smaller ones near the outlet for this purpose.

The upper-header tunnels continue downstream from the penstocks and terminate in the canyon-wall outlet works. Below the penstocks the steel headers in diversion tunnels Nos. 2 and 3 also continue to a series of outlets in a tunnel plug about 650 feet downstream from the last penstock. All these outlets will permit water to by-pass the turbines and to discharge into the river channel below. The canyon-wall outlet works are at elevation 820, about 180 feet above the normal tailrace water surface; and, when water is passing through them, a solid stream 84 inches in diameter will issue straight out from each and fall that distance in a wide trajectory to the tailrace. In most of the sketches of the project, as it will appear when completed, these streams, issuing from far up on the canyon wall on each side, are shown as a conspicuous feature.

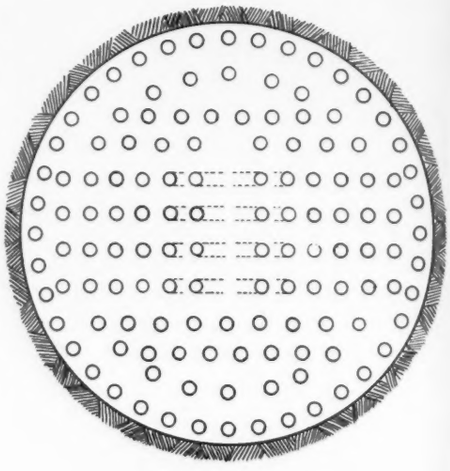
The outlet works on each side of the river are substantially alike. Downstream from the construction adit the upper header tunnel is excavated to a diameter of 35 feet and, at the lower end, six horseshoe-shaped tunnels, 11x11 feet in section, split off and come out to the canyon wall. Beyond the penstocks the steel lining contracts to a diameter of 25 feet and terminates in the outlet tunnels in six pipes, each 102 inches in diameter. The outlet tunnels will not be lined until the pipes are in place, and then concrete will be forced solidly between the piping and the tunnel walls with air under pressure. Each outlet will be closed with an 84-inch internal differential needle valve. The tunnels for these works are nearing completion.

SCALING WALLS

Ever since Six Companies Inc. moved into Black Canyon the scaling of the walls of the gorge has been in progress. It has been necessary not only to remove loose and projecting bowlders but also, in many cases, to cut back into the solid rock itself to provide footholds, anchorages, and keyways of one sort or another. The scalers, inured to the hazards of their work, sit in bos'n's chairs suspended on ropes from high above. Here are shown a group of these workers scaling down the Nevada side of the canyon wall in the area where a part of the power house will be built.

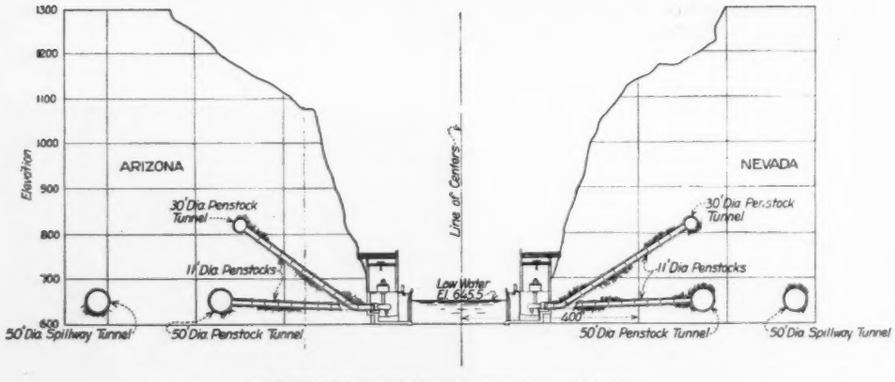
The steel headers in the diversion tunnels also contract to a diameter of 25 feet after they pass the penstocks and, several hundred feet lower down, end in a series of outlets in plugs in the diversion tunnels. At the plugs each 25-foot header branches into three 13-foot pipes and each 13-foot pipe branches into two 86-inch pipes. These six outlets pass through the plug in horizontal rows 16 feet apart. The six 72-inch hydraulic needle valves closing the outlets will be operated from a chamber above them. Access to the valve chambers will be had through horseshoe-shaped adits leading to the landing platforms of the 150-ton cableway in the canyon. Water through these outlets will flow down the diversion tunnel to the river. Through the turbines and these outlets combined will be discharged 120,000 cubic feet of water per second. Of this, 34,000 will be for maximum power generation and the rest will be valve discharge. By contrast, the maximum capacity of each spillway will be 200,000 cubic feet per second.

While these works are being carried to completion, the river bed is being rapidly excavated down to solid rock preparatory to the building of the dam, itself.



DRILLING ROUND

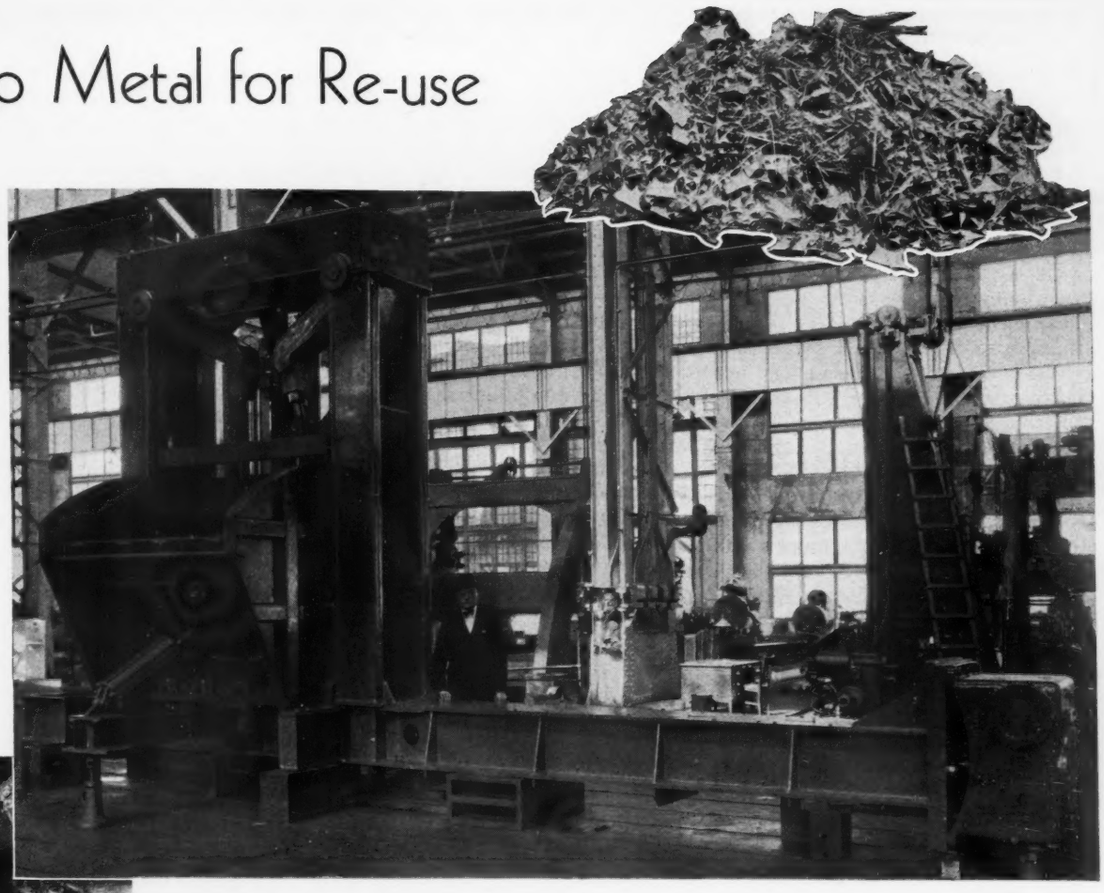
This diagram shows the approximate number and the positions of the drill holes in a normal round in the face of the 41-foot penstock header tunnels. The four inner cut holes in each vertical row on either side of the center are drilled at angles so that the opposing holes tend to converge at a depth of about 14 feet. The two outer and adjoining rows of cut holes are drilled at angles to depths of about 18 feet. After the inner and outer cut holes have been fired, the vertical rows on either side of them are shot, usually with four delays, thus breaking out a horizontal section the full width of the tunnel. Next are fired some of the horizontal rows above the center, followed by those below the center, the shooting terminating with the remaining holes at the top. After they are lined with concrete, these tunnels will be 37 feet in diameter.



SECTION THROUGH POWER HOUSE

This Bureau of Reclamation drawing shows clearly the general arrangement of the tunnels and power houses. The dam footings will be approximately 140 feet below the base level shown here, and the crest of the structure will be at elevation 1,282.

Baling Scrap Metal for Re-use



POWERFUL PRESSES

reduce bulky thin-metal scrap (upper right) into compact bundles (lower left) that are easy to handle in shipping and remelting. The machine at the right is in one of the Vulcan Detinning Company plants, and has a maximum capacity of one bale every 22 seconds. The press is operated electrically and has a pneumatic hopper door to speed up bundling.

POWERFUL briquetting machines and baling presses that greatly reduce the bulk of scrap metal have been instrumental of late years in promoting the salvage of this material especially in large industrial establishments where thousands of tons of it are produced or handled annually. In the plants of The Vulcan Detinning Company, at Sewaren, N. J., and at Pittsburgh, Pa., are several such presses of the newest type that were especially developed to meet that company's needs—to bale tin plate and other similar scrap. They can, however, handle any other sheet- or thin-metal scrap, and have been used successfully in bundling for remelting such waste materials as auto radiators stripped of their ferrous fittings, nonferrous round and flat wire, etc.

In a previous issue of COMPRESSED AIR MAGAZINE we made mention of the Southwark briquetting machine that reduces metal borings, chips, and the like to a compact mass having a density of approximately 85 per cent of the metal. Now we are dealing with presses that turn out bales having a maximum density of 38 per cent. They are being extensively employed in the plants of the aforementioned company for baling scrap metal for storage and shipment as well as for charging into cupolas or open-hearth furnaces. The material for the latter purpose is compressed to a higher density than that for storage so that the metal will melt and not vaporize and so as to reduce to a minimum the amount of metal carried away by the blast. This necessitates two types of machines which, however, differ little in general principle.

Each press is charged with an orange-peel bucket having a rated capacity of about 9 cubic feet. Actually, however, because of the nature of the material, it handles much larger quantities so that one or, at most, two bucket loads will suffice to feed the hopper, which is 78 inches wide and 48 inches front to back. In the case of the first-mentioned machine, an air cylinder serves to close the door of the hopper when filled. With this exception the press is electrically operated and functions automatically.

A vertical compression ram moves downward a distance of 72 inches and reduces the scrap to a bundle measuring 16x16x78 inches. Next, a horizontal or secondary ram, with a stroke of 108 inches, exerts pressure against the bundle, cutting down its length according to the amount of the contained scrap. At this stage the bale previously formed serves as a stop, so to speak, at the discharge end of the box in which the loose metal is compacted, and is held the while by pneumatic pawls. The latter are not released until the horizontal ram is near the end of its compression stroke. Then the first bale is ejected by the following bale, which thereupon becomes the stop and is gripped by the detents, which are reset for the purpose.

The press that bundles the scrap for remelting is a heavier machine, is hydraulically operated, and is automatic in its action from the time the man in charge trips the pneumatic lever that closes the hopper door until the bale is formed. The complete working cycle is about 22 seconds, and in that interval the hopper is charged ready for the next cycle. The loading is done before the secondary ram has completed its return stroke—thus materially increasing the operating speed. Power for the latter machine is furnished by two electrically driven hydraulic pumps: one, delivering to an accumulator at 2,000 pounds pressure per square inch, operates the primary compression ram and performs other essential work, while the second unit, pumping 470 gallons a minute at a maximum pressure of about 1,250 pounds per square inch, serves only the secondary compression ram. This press is handling regularly 28 tons of scrap an hour or turning out about 140 bundles weighing on an average 400 pounds each. Including car shifting and other duties not directly connected with the machine, the item of labor amounts to 0.08 man-hour per gross ton of baled scrap. These presses are manufactured by the Baldwin-Southwark Corporation under a license from The Vulcan Detinning Company.

LOCOMOTIVE EQUIPPED TO CHECK ALIGNMENT OF TRACKS

FOR detecting, measuring, recording, and marking vertical irregularities in the alignment of its trackage, the Victorian Railways of England have added to their rolling stock a locomotive that is especially equipped with what is known as the Cardew track-depression indicator. This instrument depends for its operation on the relative vertical movement between the leading and the trailing wheels when passing over irregularities in the vertical alignment of the track. This movement is transmitted to an electric make-and-break mechanism or detector, causing it to operate.

There are two of these detectors on the locomotive, so that both rails can be checked simultaneously. They are mounted on the side frames and connected with the axle boxes of the aforementioned coupled wheels. Deep depressions are indicated by the lighting of a red lamp, the operation of a counter, and the functioning of a paint spray which automatically marks the location of the faults within 2 or 3 feet of them. If desired, the hills and dales can be registered on a chart by the energizing of a pen. Depressions of moderate depth are indicated by a yellow light. The track-testing locomotive is run regularly once a month over certain sections of the main line. The device is the invention of C. A. Cardew, who is an engineer on the New South Wales Railways.

NEW FOUR-WAY AIR VALVE

THE new 4-way poppet valve of the Q-C Engineering Products, Detroit, Mich., is named the "Sav-Air" because half of the operating cycle—the return movement—is effected without drawing upon the line for operating pressure. With the handle of the "Sav-Air" in the central or neutral position, all the valves are closed but both sides of the cylinder are connected by means of the valves. Shifting the handle to the first right-hand position opens the exhaust to the left-hand side of the cylinder; shifting the handle to the second right-hand position fully opens the exhaust and admits full line pressure to the right-hand side of the piston to perform work.

On bringing the handle back to the first right-hand position and then to neutral, the right-hand side of the piston is disconnected; the left-hand side exhaust valve is closed; and the air is bled from the right to the left side of the piston until the pressure on both sides is equalized. When the handle has passed the neutral position and is on its way to the first left-hand position, the right-hand exhaust valve starts to open but not until after all the air is bled. It is the air flowing from the right to the left side of the piston that effects the return movement except when heavier work demands the use of air at higher pressure. Any unintentional use of high-pressure air from the line is obviated by a heavy spring that is not released until the handle has been brought to the second left-hand position. For work requiring both the operator's hands, the "Pedair," a foot-control valve of the same type, is available.

METAL FILLERS FOR SPECIAL PIPE-BENDING JOBS

RESIN, pitch, and sand—fillers used in bending metal pipes—have a rival now in the form of an alloy appropriately named "Bendalloy." The new material is marketed by the Cerro de Pasco Copper Corporation, New York City, and is composed of bismuth, lead, tin, and cadmium. It fuses at a temperature of 160° F.

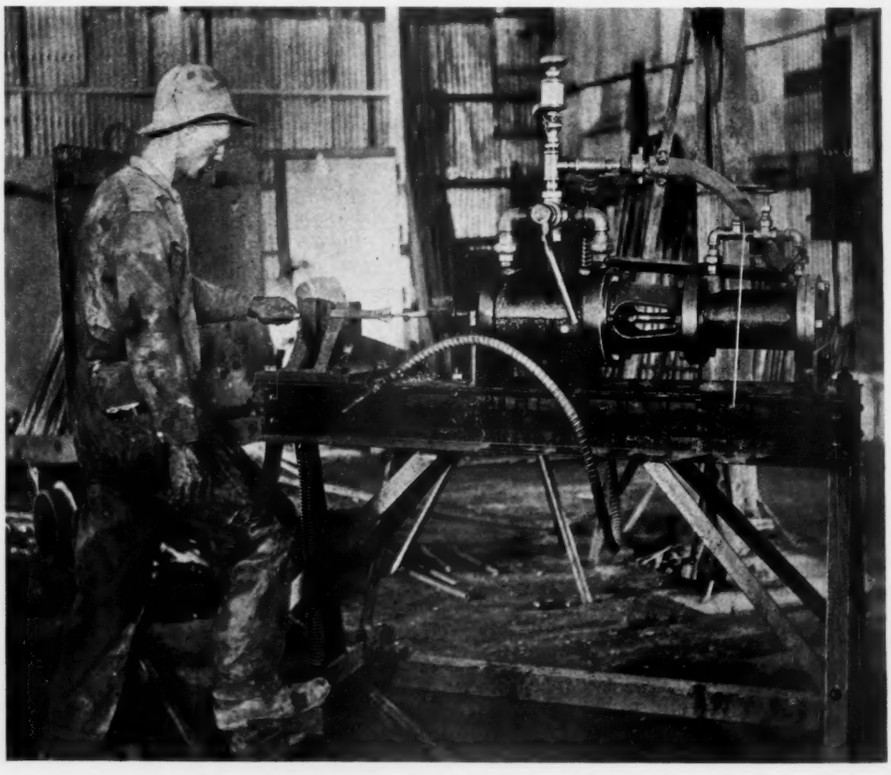
Reduced to the molten state, the metal is poured into the tube to be bent and allowed to chill there, forming a close-grained filler that makes it possible to shape pipe lengths without distortion—the bending being done slowly and under a uniformly applied load. The outstanding advantage of the alloy, as compared with the materials ordinarily used for the purpose, is that it can be easily removed—that is, fused—by immersing the tube in boiling water, leaving its inner walls smooth and clean. For this reason it is finding favor in airplane factories in shaping the oil, gas, and water lines in which there must be no trace of foreign matter, something that cannot always be guaranteed with sand, resin, or the like

"Bendalloy" is suitable for all but lead pipe, and is intended for special jobs—not quantity production—involving anywhere from 1 to 100 difficult bends of a certain kind.

REFRACTORY MATERIAL FROM CHROME-STEEL SLAG

UNDER the trade name of "Siemensit" is being produced in Germany a new refractory for which is being claimed exceptional heat-resisting properties. The basic material is slag obtained in the manufacture of chrome steel. The product is the outcome of laboratory work purposely undertaken to find a use for this hitherto waste material.

"Siemensit" is composed principally of the oxides of chromium, magnesium, and aluminum, and is poured directly into blocks from the molten state. According to tests conducted at the Chemical Laboratory for the Clay Industry in Berlin, the material is exceedingly dense in structure, has a high modulus of elasticity, and is a good conductor of heat. The blocks remained unaltered during fire-resistance tests at Seger cone 42, the highest in the scale; and under a load of 2 kilograms per square centimeter withstood temperatures up to 3,290° F.—the maximum available in the laboratory. Without loading, the maximum expansion was 1.2 per cent. Sample specimens are said to have undergone no change when subjected to the action of various slags and molten sodium sulphate, thus proving the refractory well adapted for use in kilns and furnaces that now represent a troublesome problem because of such attack.



ANCESTOR OF SHANK-AND-BIT PUNCH

Mining men and contractors will find the above picture interesting. It shows what is possibly the great-great-grand-daddy of all modern shank-and-bit punches which are used in connection with drill-steel sharpeners to keep the hole in hollow drill steel clear and of full size. It was improvised at one of the properties of the Phelps Dodge Corporation, to which concern we are indebted for the illustration. The machine was made up of two cylinders from an old steam pump. One served only as a dashpot and was retained merely because both cylinders had been joined together in the pumping unit.